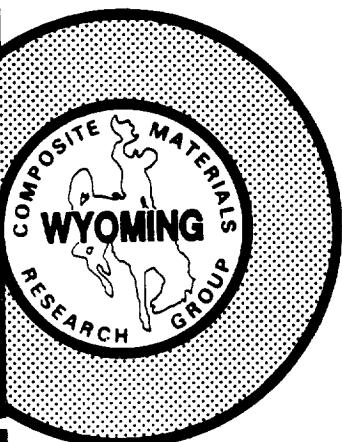


**STATIC TENSILE AND TENSILE CREEP
TESTING OF FOUR BORON NITRIDE
COATED CERAMIC FIBERS
AT ELEVATED TEMPERATURES**



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Scott L. Coguill
Donald F. Adams
Richard S. Zimmerman

August 1989

FINAL REPORT

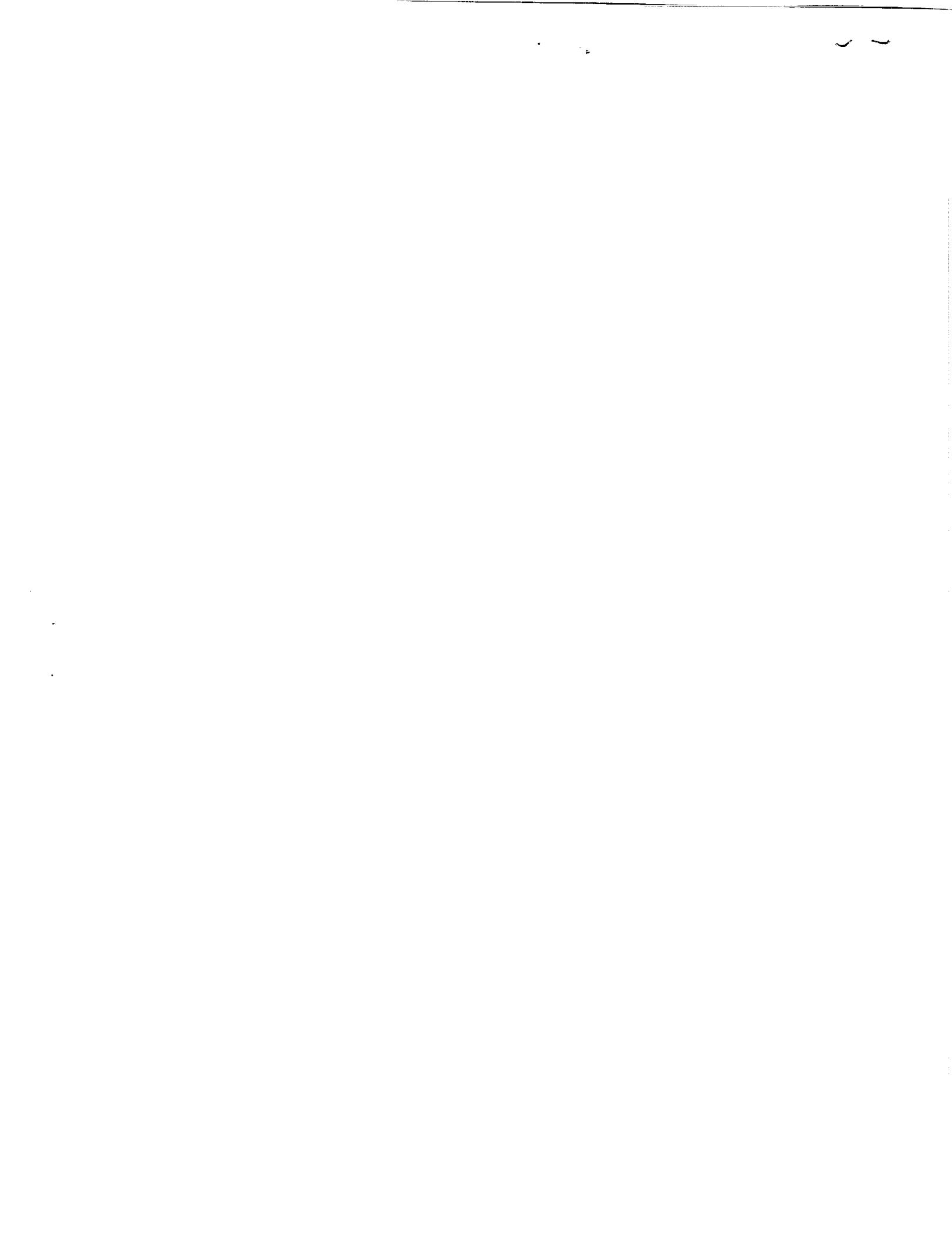
**NASA-Ames Research Center
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**COMPOSITE MATERIALS RESEARCH GROUP
DEPARTMENT of MECHANICAL ENGINEERING
University of Wyoming Laramie, Wyoming 82071**



REPORT UW-CMRG-R-89-123

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PREFACE

This technical report presents the results of a study, sponsored by NASA-Ames Research Center under Grant No. NAG 2-470, dated July 1, 1987. Dr. Demetrius A. Kourides served as the NASA-Ames Technical Monitor.

All work was conducted by the Composite Materials Research Group (CMRG) within the Department of Mechanical Engineering at the University of Wyoming. Co-Principal Investigators were Mr. Richard S. Zimmerman, Staff Engineer, and Dr. Donald F. Adams, Professor. Making significant contributions to this program were Messrs. Hal Radloff and Steve Bartel, undergraduate students in Mechanical Engineering and members of the Composite Materials Research Group. This report was compiled by Mr. Scott L. Coguill, Staff Engineer.

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SECTION 1

INTRODUCTION

Six types of uncoated ceramic fibers and four types of boron nitride coated ceramic fibers were static tensile tested at room temperature and four elevated temperatures. The boron nitride coated fibers and one of the uncoated fibers were also creep tested at four elevated temperatures. Testing was performed on single fibers separated from tows supplied by NASA-Ames. The six uncoated ceramic fibers chosen for this program were J.P. Stevens Co. Astroquartz 9288 glass fiber, Nippon Carbon, Ltd. (Dow Chemical) Nicalon NLM-102 silicon carbide fiber, and 3M Company Nextel 312, Nextel 380, Nextel 440, and Nextel 480 alumina/silica/boria fibers. The boron nitride coated fibers tested were the Nicalon NLM-102, and the Nextel 312, 440, and 480 fibers.

The complete test matrix is given in Tables 1 and 2. ASTM Standard Test Method D 3379-75 was used as the reference test procedure for all testing [1].

Each type of fiber was initially static tensile tested at gage lengths of 1, 2, and 4 inches, at room temperature, to determine the magnitude of end effects from the paper end tabs and grips. No creep testing was performed at room temperature. Each type of fiber was also initially static tensile tested at gage lengths of 8 and 10 inches, at one of the elevated test temperatures, to determine end effects for the elevated temperature static and creep testing. An end effect

Table 1
Test Matrix for Each Type of Uncoated Ceramic Fiber

| Fiber Type | Test Method | Test Temperature (°C) | Gage Length (inches) | No. of Replicates |
|------------------|-------------|-----------------------|----------------------|-------------------|
| Astroquartz 9288 | Static | 25 | 1 | 10 |
| | | | 2 | 10 |
| | | | 4 | 10 |
| | | 500 | 8 | 5 |
| | | | 10 | 5 |
| | | 600 | 8 | 5 |
| | | | 8 | 5 |
| | | | 8 | 5 |
| | | 800 | 8 | 5 |
| | | | 8 | 5 |
| Nicalon NML-102 | Static | 25 | 1 | 10 |
| | | | 2 | 10 |
| | | | 4 | 10 |
| | | 1000 | 8 | 5 |
| | | | 10 | 5 |
| | | 1100 | 8 | 5 |
| | | | 8 | 5 |
| | | | 8 | 5 |
| | | | 8 | 5 |
| Nextel 312 | Static | 25 | 1 | 10 |
| | | | 2 | 10 |
| | | | 4 | 10 |
| | | 400 | 8 | 5 |
| | | | 8 | 5 |
| | | 500 | 10 | 5 |
| | | | 8 | 5 |
| | | | 8 | 5 |
| | | | 8 | 5 |
| Nextel 380 | Static | 25 | 1 | 10 |
| | | | 2 | 10 |
| | | | 4 | 10 |
| | | 600 | 8 | 5 |
| | | | 10 | 5 |
| | | 700 | 8 | 5 |
| | | | 8 | 5 |
| | | | 8 | 5 |
| | | | 8 | 5 |

Table 1 (cont.)

| Fiber Type | Test Method | Test Temperature (°C) | Gage Length (inches) | No. of Replicates |
|------------|-------------|-----------------------|----------------------|-------------------|
| Nextel 440 | Static | 25 | 1 | 10 |
| | | | 2 | 10 |
| | | | 4 | 10 |
| | | 500 | 8 | 5 |
| | | | 10 | 5 |
| | | 600 | 8 | 5 |
| | | | 10 | 5 |
| | | 700 | 8 | 5 |
| | | | 10 | 5 |
| | | 800 | 8 | 5 |
| Nextel 480 | Creep | 500 | 8 | 3 |
| | | 600 | 8 | 3 |
| | | 700 | 8 | 3 |
| | | 800 | 8 | 3 |
| Nextel 480 | Static | 25 | 1 | 10 |
| | | | 2 | 10 |
| | | | 4 | 10 |
| | | 900 | 8 | 5 |
| | | 1000 | 8 | 5 |
| | | | 10 | 5 |
| | | 1100 | 8 | 5 |
| | | 1200 | 8 | 5 |

Table 2
Test Matrix For the Four Boron Nitride Coated Ceramic Fibers

| Test Method | Test Temperature (°C) | Gage Length (inches) | No. of Replicates |
|-------------|-----------------------|----------------------|-------------------|
| Static | 25 | 1 | 10 |
| | | 2 | 10 |
| | | 4 | 10 |
| | 500 | 8 | 10 |
| | | 10 | 10 |
| | 600 | 8 | 10 |
| | | 10 | 10 |
| | 700 | 8 | 10 |
| | | 10 | 10 |
| | 800 | 8 | 10 |
| | | 10 | 10 |
| Creep | 500 | 8 | 3 |
| | 600 | 8 | 3 |
| | 700 | 8 | 3 |
| | 800 | 8 | 3 |

correction was found to be unnecessary for the elevated temperature testing. All subsequent elevated temperature testing, both static and creep, was thus performed utilizing only 8 inch long specimens.

As will be noted in Tables 1 and 2, the creep test temperatures used were slightly lower than the static tensile test temperatures. This was to compensate for the much longer time the fibers being creep tested spent at the elevated temperatures. The high temperatures for long durations were causing severe degradation of the fibers. Static testing nominally subjected each fiber to the elevated temperature for only 1 to 3 minutes. The creep test duration was nominally four hours. Exposure in an air atmosphere at the highest temperatures for this comparatively long time was found to degrade the ceramic fibers too much. Thus, lower test temperatures for creep were utilized to ensure properties could be measured.

A summary of all of the test results is presented in the next section. Specimen fabrication techniques and descriptions of the test apparatus used can be found in Reference [2], which is the previous report on single ceramic fiber testing. Test methods and detailed experimental results are given in Section 3. Appendix A contains the individual single fiber static tensile test results, while Appendix B contains individual tensile creep test results.

SECTION 2

SUMMARY OF RESULTS

Single fiber static tensile testing at various elevated temperatures was performed on all ten uncoated and boron nitride coated types of ceramic fibers supplied by NASA-Ames. The boron nitride coated ceramic fibers and one of the uncoated fibers were subject to tensile creep testing at various elevated temperatures. All uncoated fibers were supplied as untwisted rovings, both sized and unsized. The single fibers used for all testing were carefully separated by hand from the unsized rovings. It was found that sized fibers could not be utilized since the fibers adhered to each other to such a great degree that individual fibers could not be extracted from the fiber bundles without damaging them.

Static testing was performed on each of the uncoated and coated ceramic fibers at room temperature and four elevated temperatures, to provide baseline data for each fiber type. Because of the differences in temperature sensitivity of the different types of fibers, each type was tested at a slightly different set of elevated temperatures, selected to be consistent with the sensitivity of that particular fiber. The creep testing was only performed on the four boron nitride coated ceramic fibers and on the uncoated Nextel 440 ceramic fiber. Additional creep data on uncoated fibers is presented in Reference [2]. All creep tests were to be conducted at a stress level equal to at least 40 percent of the corresponding static tensile strength measured at that

test temperature. This was the highest stress level the boron nitride coated fibers could withstand. Higher stresses caused the fibers to fail while loading the creep fixture. Actual creep stress levels varied for the four boron nitride coated fiber types due to limits imposed by the strain measurement instrumentation and widely varying fiber sizes encountered. The strain measurement limit was 2 percent, dictated by the small LVDTs used to measure fiber displacements and the long specimen gage lengths. The uncoated Nextel 440, the boron nitride Nextel 312 and the boron nitride Nextel 480 fibers were creep tested nominally at 40 percent of their ultimate stress levels. The boron nitride Nicalon NLM-102 and the boron nitride Nextel 440 fibers were creep tested nominally at 50 percent of their ultimate stresses. These stress levels kept strain measurements within the above mentioned limits for all fibers. All creep testing was performed at the same test temperatures as the static tensile testing.

Data are presented in graphical form in this summary, to provide the reader with relative magnitudes and temperature capabilities for the different types of coated ceramic fibers. As will be noted, the test temperatures were quite different. Thus, comparisons of fiber properties should be made carefully, to avoid improper conclusions as to the capability of each fiber at elevated temperature. For each of the types of fibers, testing was performed up to the highest temperature that still yielded reasonable mechanical properties. It was found that properties fell dramatically above the highest temperatures reported here.

Average static tensile properties for the boron nitride coated ceramic fibers are shown in Figures 1 through 3, while average tensile

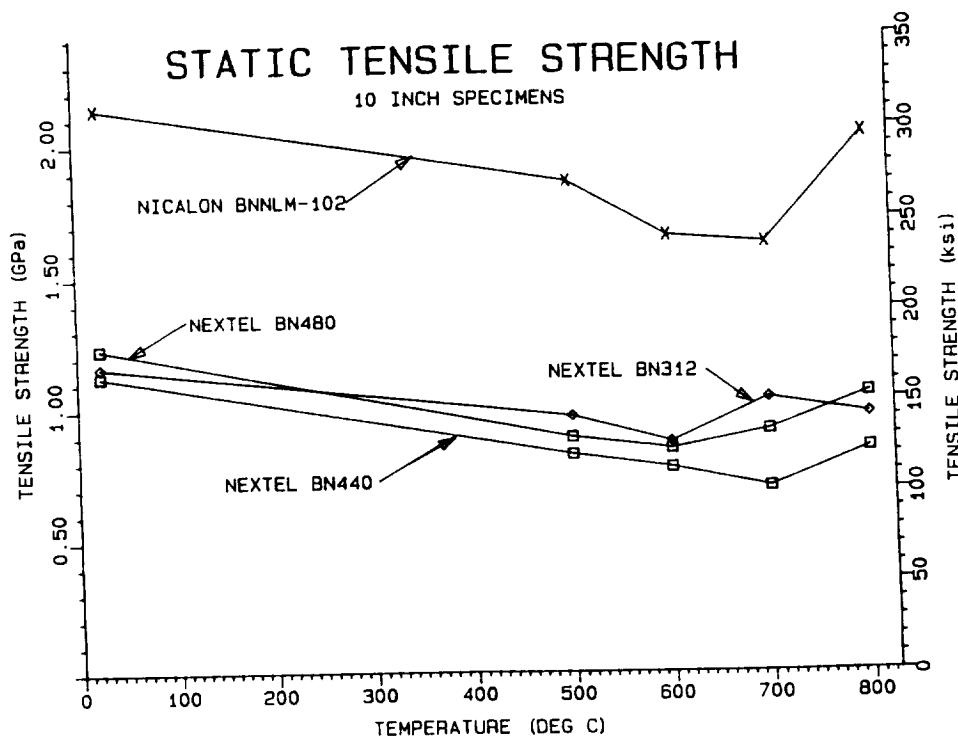
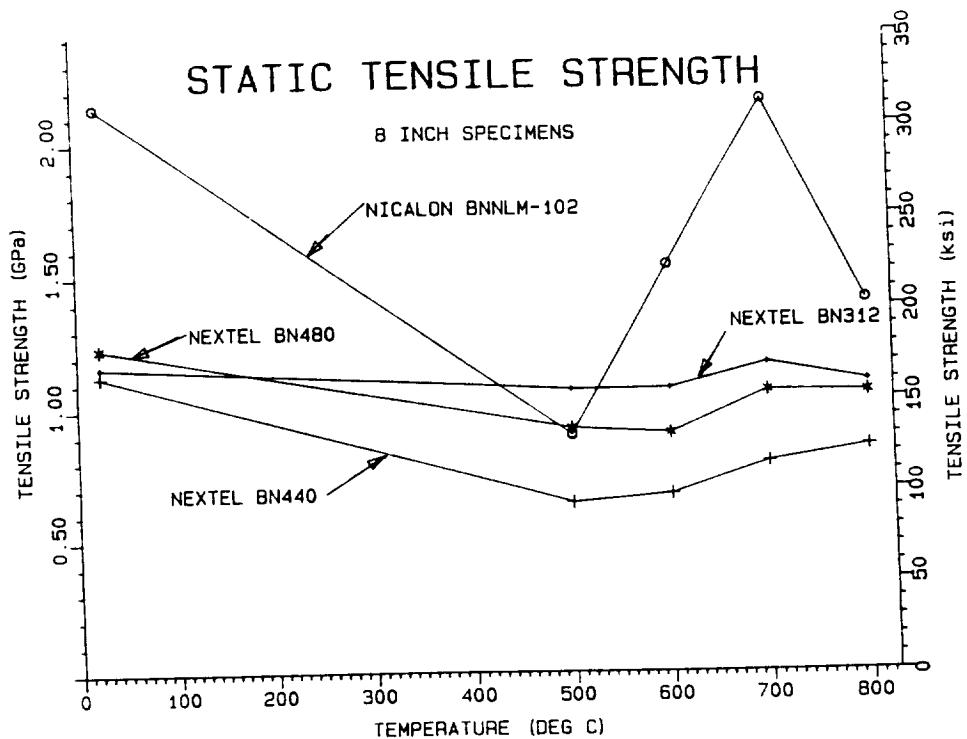


Figure 1. Average Static Tensile Strengths of Single Boron Nitride Coated Ceramic Fibers at Two Specimen Lengths.

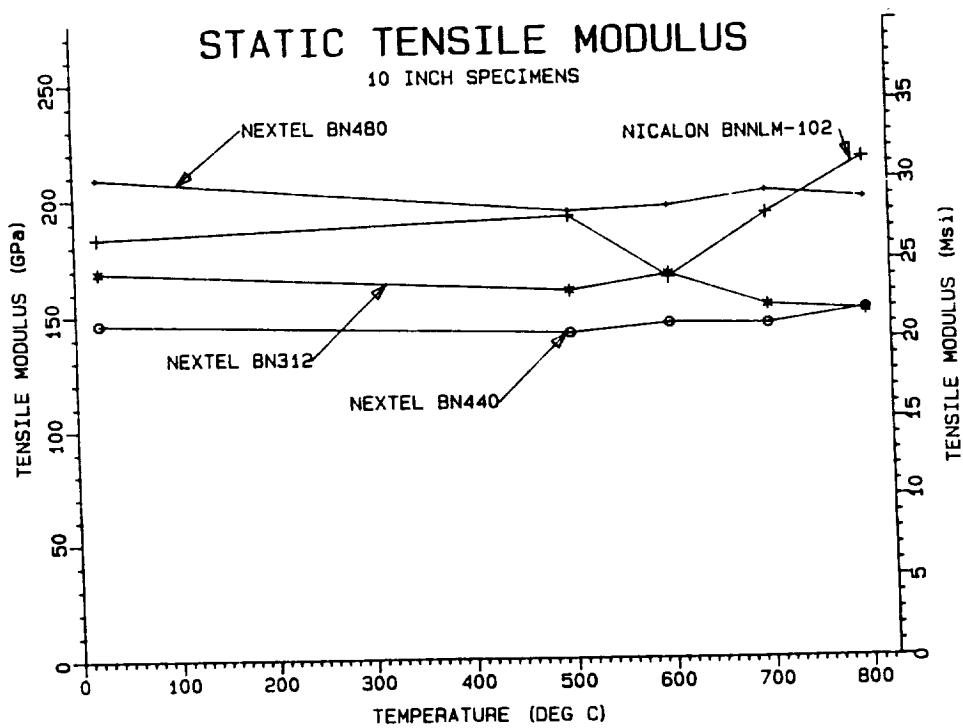
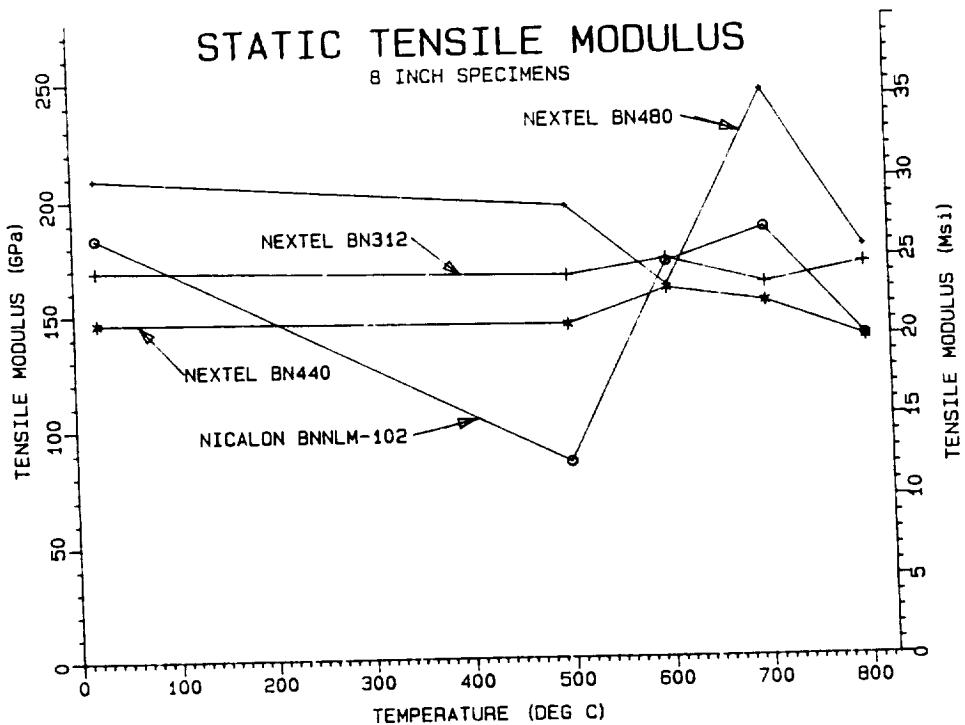


Figure 2. Average Static Tensile Moduli of Single Boron Nitride Coated Ceramic Fibers at two Specimen Lengths.

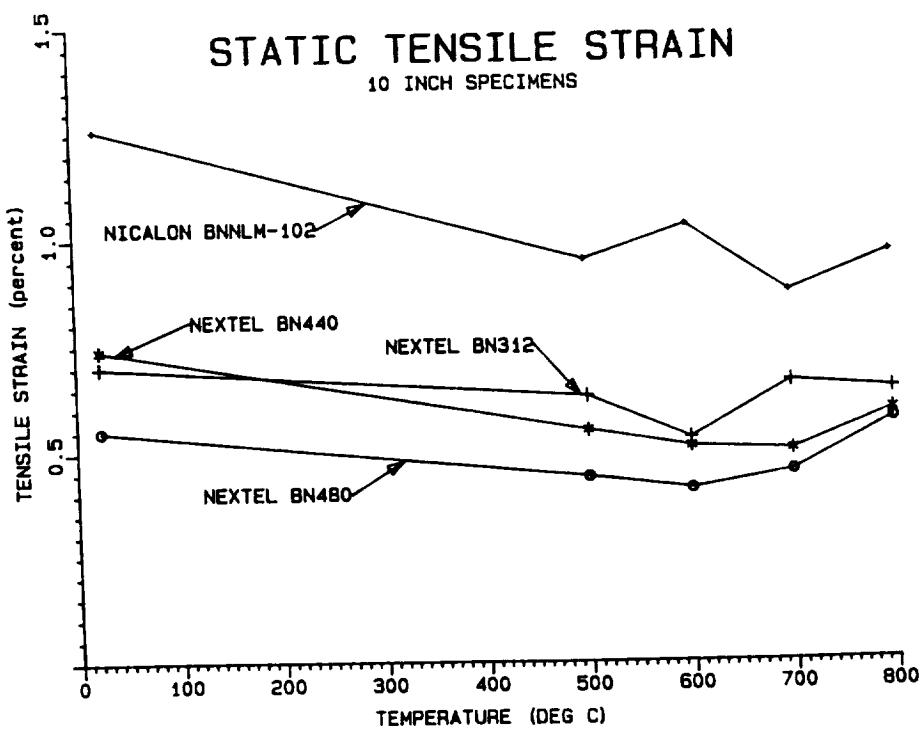
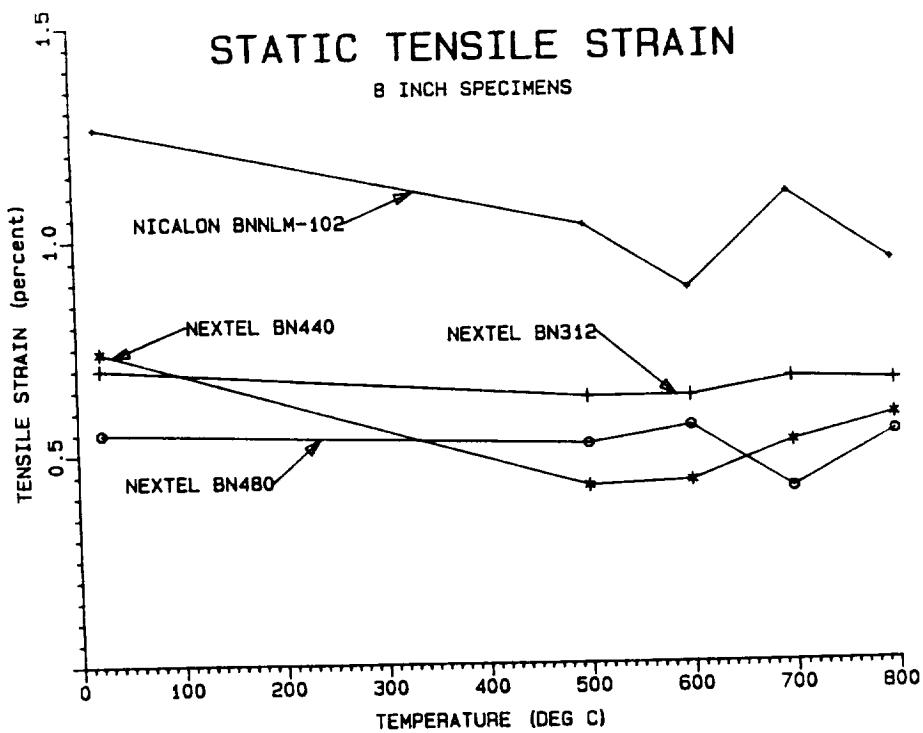


Figure 3. Average Static Tensile Strains of Single Boron Nitride Coated Ceramic Fibers at Two Specimen Lengths.

creep rates are shown in Figure 4. The average data presented here in graphical form are presented again in tabular form in Section 3. Individual test specimen results are presented in Appendices A and B.

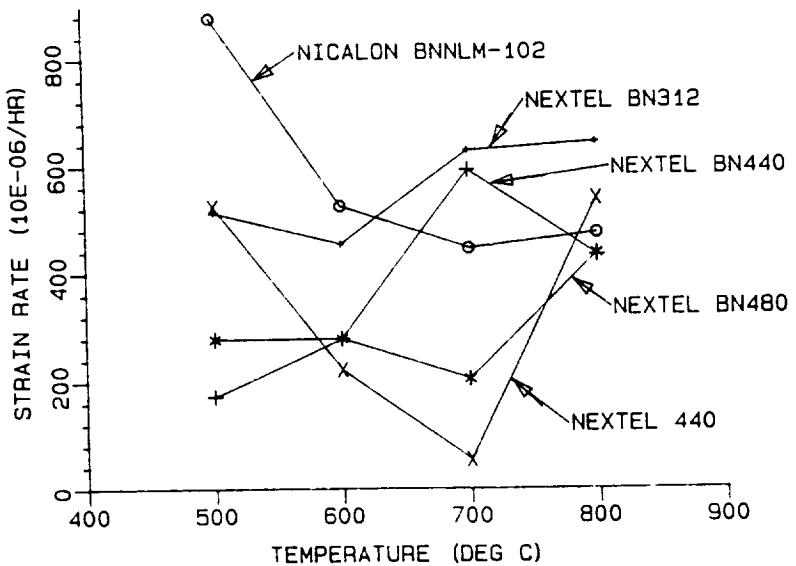
Some experimental work had been performed previously by other researchers using fiber tows to determine similar properties for the six uncoated materials tested in this study [3-5]. Considerable effort was expended here in developing the required test apparatus for performing single fiber static tensile and tensile creep tests. Single fiber testing requires a great deal of patience and care in specimen preparation due to the fragile nature of the fibers and the affinity of the fibers for other fibers in the tow. Careful handling is also critical once specimens are fabricated, to ensure the fiber specimens are not damaged prior to testing.

A scanning electron microscope (SEM) was used to photograph groups of fibers, to provide an overall indication of the fiber diameters and shapes, and their variations.

The test specimen configuration and test apparatus used for static tensile and tensile creep are described in detail in Reference [2].

CREEP STRAIN RATE

(SLOPE TAKEN BETWEEN 1/2 HOUR AND 1 HOUR OF TEST)



CREEP STRAIN RATE

(SLOPE TAKEN BEWTEEN 1/2 HOUR AND END OF TEST)

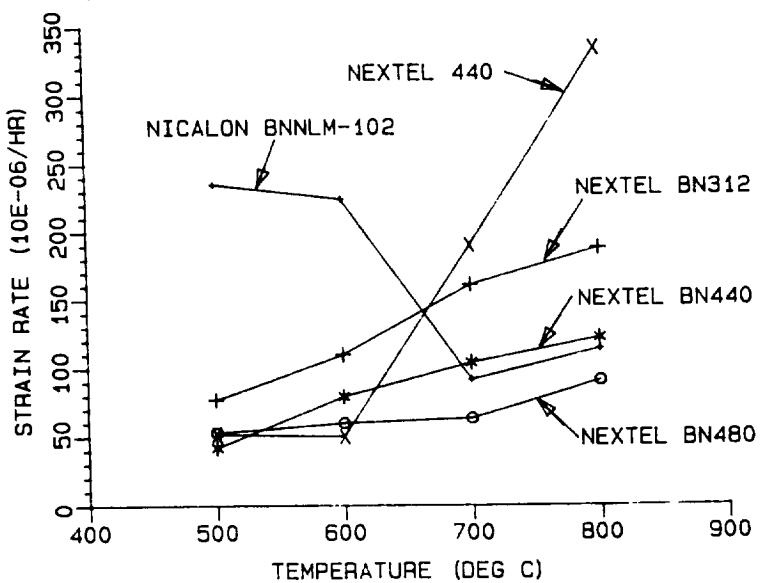


Figure 4. Average Tensile Creep Strain Rates of Single Boron Nitride Coated Ceramic Fibers.

SECTION 3

EXPERIMENTAL RESULTS

The six uncoated fibers tested were J.P. Stevens Astroquartz 9288 glass fiber, Nippon Carbon, LTD. (Dow Corning) Nicalon NLM-102 silicon carbide fiber, and 3M Company Nextel 312, Nextel 380, Nextel 440, and Nextel 480 alumina/silica/boria fibers. The four boron nitride coated fibers were Nicalon NLM-102, Nextel 312, Nextel 440, and Nextel 480. The six uncoated ceramic fibers were static tensile tested at room temperature and four elevated temperatures. The four coated fibers, as well as the uncoated Nextel 440, were tensile creep tested at the four elevated temperatures listed in Table 2 of Section 1. No creep testing was performed at room temperature.

Young's modulus, tensile strength, tensile strain, and creep strain, were the mechanical properties determined at each test temperature for the six types of fibers.

Average test results are presented here while individual test data are given in Appendix A.

3.1 Scanning Electron Microscope Observations

All fiber types were photographed using a scanning electron microscope (SEM) to determine their typical shapes and diameters. This determination was very important since it was necessary to calculate the fiber cross-sectional areas. For the present study, all data were reduced using the average cross-sectional area values determined from

the SEM photographs. Due to fiber to fiber size variations, this introduced some scatter in the data, particularly for the types of fibers that exhibited greater geometric variations. The fiber dimensions for all the uncoated fibers, except Nextel 440, were taken from Reference [2].

Reference [9] contains an equation, repeated below as Eq. (1), used by 3M Company to calculate the approximately elliptical area of the Nextel fibers.

$$\text{Area} = (\text{major dia.}) \times (\text{minor dia.}) \times (0.87) \quad (1)$$

The equation for a true ellipse is:

$$\text{Area} = (\text{major dia.}) \times (\text{minor dia.}) \times (\pi/4) \quad (2)$$

Eq. (1) was used to make the area calculations per the recommendations of the manufacturer of the Nextel fibers, the 3M Company.

Figure 5 is a SEM photograph of a group of Nextel 440 fibers. Figures 6 through 9 are SEM photographs of groups of boron nitride coated Nicalon NLM-120, Nextel 312, Nextel 440, and Nextel 480. The coating of boron nitride did not change the general shape of the fibers.

Comparisons of fiber sizes and shapes obtained from the SEM study are given in Table 3.

3.2 Static Tensile Test Results

Table 4 presents average static tensile strengths, moduli, and strains to failure for the six types of uncoated ceramic fibers. The



Figure 5. Scanning Electron Microscope Photograph of a Group of Nextel 440 Fibers.



Figure 6. Scanning Electron Microscope Photograph of a Group of Coated Nicalon NLM-102 Fibers.

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BLACK AND WHITE PHOTOGRAPH



Figure 7. Scanning Electron Microscope Photograph of a Group of Coated Nextel 312 Fibers.



Figure 8. Scanning Electron Microscope Photograph of a Group of Coated Nextel 440 Fibers.

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Figure 9. Scanning Electron Microscope Photograph of a Group of Coated Nextel 480 Fibers.

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Table 3
 Average Fiber Dimensions as Measured from
 Scanning Electron Microscope Photographs

| Fiber Type | Fiber Shape | Diameter (μm) | Area (μm^2) |
|------------------------|-------------|-------------------------------|-----------------------------|
| Astroquartz 9288 | round | 8.75 | 60.1 |
| Nicalon NLM-102 | round | 13.8 | 149.6 |
| Nextel 312 | ellip. | 7.8 by 12.5 | 84.8 |
| Nextel 380 | ellip. | 8.2 by 13.2 | 94.2 |
| Nextel 480 | ellip. | 7.2 by 11.5 | 72.0 |
| Nextel 440 | ellip. | 7.8 by 13.0 | 88.2 |
| Coated Nicalon NLM-102 | round | 14.9 | 174.4 |
| Coated Nextel 312 | ellip. | 7.8 by 13.0 | 88.2 |
| Coated Nextel 440 | ellip. | 9.8 by 13.5 | 115.1 |
| Coated Nextel 480 | ellip. | 9.8 by 12.5 | 106.6 |

Note: The values for the first five fibers listed are from Reference [2].
 Area of elliptical shapes = (major dia.) \times (minor dia.) \times (0.87) [9].

six types of fibers were tested at the highest temperatures that still gave reasonable mechanical properties for that type of fiber. Each fiber was tested at slightly different temperatures, as indicated in Tables 1 and 4. The maximum reasonable test temperatures were all determined in Reference [2], except the test temperatures for Nextel 440, which were evaluated during this study.

Fiber strength was the major parameter used in establishing the highest temperatures the fibers were to be tested at. It will be noted in Table 4 that the fiber modulus values did not show as much of a drop as the fiber strengths. All of the fibers suffered losses in tensile strength at the higher test temperatures well before they exhibited much loss of stiffness.

Table 4 also presents average static tensile strains to failure for the six types of ceramic fibers tested in this program. As the table indicates, the average ultimate strains for all of the fibers were less than two percent, and did not vary significantly as a function of test temperature.

Table 5 presents the average static tensile test results for the four boron nitride coated ceramic fibers. The elevated test temperatures were the same as those used in the creep tests.

Figures 10 through 16 portray the effect of the boron nitride coating on static tensile test results. Only test results on coated and uncoated fibers at the same test temperature were compared. This only allowed the direct comparison of two fiber types, coated and uncoated Nextel 312 and 440.

As the tables and figures indicate, the boron nitride coating improved the static tensile performance of the Nextel 312 fiber, but

Table 4
Average Static Tensile Data for Single Uncoated Fibers

| Fiber Type | Test Temp. (°C) | Gage Length (in.) | Tensile Strength (GPa) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) | |
|------------------|-----------------|-------------------|------------------------|-----------------------|-----------------------|---------------------------|--|
| Astroquartz 9288 | 23 | 1 | 0.81 | 118 | 72 | 10.5 | |
| | | 2 | 0.78 | 112 | 73 | 10.6 | |
| | | 4 | 0.70 | 101 | 79 | 11.4 | |
| | 500 | 8 | 1.19 | 146 | 80 | 11.6 | |
| | | 10 | 1.53 | 222 | 84 | 12.2 | |
| | 600 | 8 | 1.13 | 164 | 71 | 10.3 | |
| | 700 | 8 | 1.02 | 148 | 73 | 10.6 | |
| | 800 | 8 | 0.79 | 115 | 70 | 10.1 | |
| | 1000 | 1 | 2.32 | 336 | 223 | 32.4 | |
| | | 2 | 2.88 | 417 | 211 | 30.5 | |
| | | 4 | 2.38 | 345 | 272 | 39.4 | |
| | | 8 | 1.83 | 265 | 250 | 36.3 | |
| | | 10 | 1.51 | 219 | 212 | 30.8 | |
| | | 1100 | 8 | 1.91 | 276 | 33.0 | |
| | | 1200 | 8 | 1.56 | 226 | 24.5 | |
| Nicalon NLM-102 | 1300 | 8 | 1.28 | 185 | 164 | 23.7 | |
| | | 1 | 2.32 | 336 | 223 | 32.4 | |
| | | 2 | 2.88 | 417 | 211 | 30.5 | |
| | 1000 | 4 | 2.38 | 345 | 272 | 39.4 | |
| | | 8 | 1.83 | 265 | 250 | 36.3 | |
| | 1100 | 10 | 1.51 | 219 | 212 | 30.8 | |
| | | 8 | 1.91 | 276 | 227 | 33.0 | |
| | 1200 | 8 | 1.56 | 226 | 169 | 24.5 | |
| | 1300 | 8 | 1.28 | 185 | 164 | 23.7 | |
| | 1300 | 1 | 2.32 | 336 | 223 | 32.4 | |
| Nextel 312 | | 2 | 2.88 | 417 | 211 | 30.5 | |
| | | 4 | 2.38 | 345 | 272 | 39.4 | |
| 400 | 8 | 1.09 | 158 | 154 | 22.4 | | |
| | 10 | 0.92 | 134 | 142 | 20.6 | | |
| 500 | 8 | 0.92 | 134 | 140 | 20.4 | | |
| | 10 | 0.97 | 140 | 161 | 23.4 | | |
| 600 | 8 | 1.15 | 166 | 110 | 16.0 | | |
| 700 | 8 | 0.75 | 109 | 19.4 | 1.25 | | |
| 700 | 1 | 1.28 | 186 | 106 | 15.4 | | |
| | 2 | 1.04 | 151 | 113 | 16.4 | | |
| | 4 | 0.74 | 107 | 125 | 18.1 | | |
| Nextel 380 | 600 | 8 | 1.40 | 204 | 160 | 23.2 | |
| | | 10 | 1.36 | 198 | 159 | 23.1 | |
| | | 8 | 1.34 | 194 | 141 | 20.5 | |
| | 700 | 8 | 0.86 | 124 | 130 | 18.8 | |
| | | 8 | 0.90 | 130 | 127 | 18.4 | |
| | 800 | 8 | 1.50 | 217 | 134 | 19.4 | |
| | | 2 | 1.39 | 202 | 149 | 21.6 | |
| | 900 | 4 | 1.10 | 159 | 135 | 19.6 | |
| | | 8 | 1.40 | 204 | 160 | 23.2 | |
| | 700 | 10 | 1.36 | 198 | 159 | 23.1 | |
| | | 8 | 1.34 | 194 | 141 | 20.5 | |
| | 800 | 8 | 0.86 | 124 | 130 | 18.8 | |
| | 900 | 8 | 0.90 | 130 | 127 | 18.4 | |

Table 4 (Continued)

Average Static Tensile Data for Single Uncoated Fibers

| Fiber Type | Test Temp. (°C) | Gage Length (in.) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|------------|--------------------|----------------------|---------------------------|---------------------------|--------------------------|--------------------------|------------------------------|
| Nextel 480 | 23 | 1 | 2.73 | 396 | 208 | 30.1 | 1.32 |
| | | 2 | 1.92 | 278 | 226 | 32.8 | 0.87 |
| | | 4 | 2.03 | 295 | 227 | 32.9 | 0.86 |
| | 23 | 1 | 2.52 | 365 | 234 | 33.9 | 1.07 |
| | | 2 | 2.42 | 350 | 245 | 35.4 | 0.93 |
| | | 4 | 1.72 | 249 | 282 | 40.8 | 0.62 |
| | 900 | 8 | 1.73 | 251 | 233 | 33.7 | 0.73 |
| | 1000 | 8 | 1.74 | 252 | 240 | 34.8 | 0.69 |
| | | 10 | 1.21 | 175 | 236 | 34.2 | 0.50 |
| | 1100 | 8 | 0.45 | 65 | 177 | 25.6 | 0.24 |
| | 1200 | 8 | 0.45 | 66 | 216 | 31.4 | 0.20 |
| Nextel 440 | 23 | 1 | 1.79 | 260 | 181 | 26.2 | 1.00 |
| | | 2 | 1.48 | 215 | 186 | 26.9 | 0.75 |
| | | 4 | 1.91 | 277 | 191 | 27.6 | 1.00 |
| | 500 | 8 | 1.50 | 217 | 196 | 28.3 | 0.73 |
| | | 10 | 1.10 | 160 | 184 | 26.6 | 0.61 |
| | 600 | 8 | 0.75 | 108 | 198 | 28.7 | 0.54 |
| | | 10 | 1.25 | 182 | 191 | 27.6 | 0.75 |
| | 700 | 8 | 1.56 | 226 | 181 | 26.3 | 0.84 |
| | | 10 | 1.32 | 192 | 189 | 27.4 | 0.75 |
| | 800 | 8 | 1.36 | 197 | 178 | 25.9 | 0.80 |
| | | 10 | 1.55 | 224 | 204 | 29.5 | 0.74 |

Table 5

Average Static Tensile Data for Single
Boron Nitride Coated Fibers

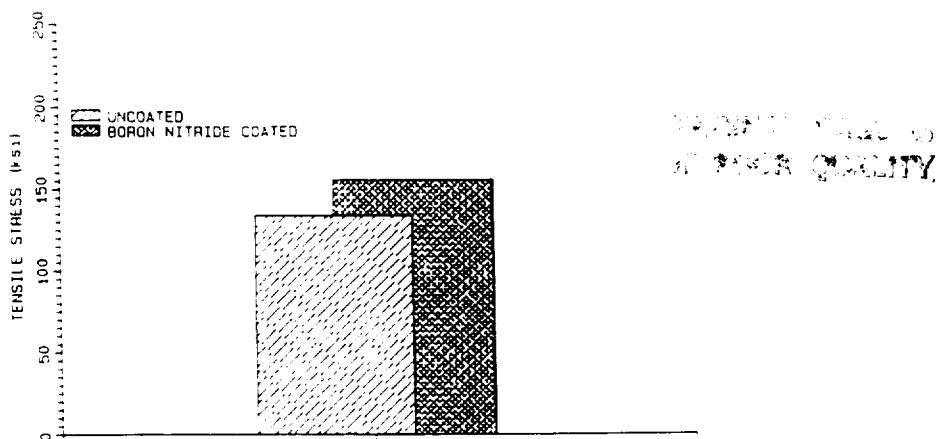
| Fiber Type | Test Temp. (°C) | Gage Length (in.) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Strength (GPa) | Tensile Strength (Msi) | Ultimate Strain (percent) |
|----------------------|--------------------|----------------------|---------------------------|---------------------------|---------------------------|---------------------------|------------------------------|
| Coated Nextel 312 | 23 | 1 | 1.35 | 196 | 161 | 23.3 | 0.79 |
| | | 2 | 1.14 | 165 | 169 | 24.5 | 0.66 |
| | | 4 | 1.17 | 169 | 169 | 24.5 | 0.70 |
| | 500 | 8 | 1.07 | 156 | 166 | 24.0 | 0.63 |
| | | 10 | 0.97 | 141 | 160 | 23.2 | 0.63 |
| | 600 | 8 | 1.08 | 156 | 173 | 25.0 | 0.63 |
| | | 10 | 0.88 | 127 | 167 | 24.2 | 0.53 |
| | 700 | 8 | 1.17 | 169 | 161 | 23.4 | 0.67 |
| | | 10 | 1.04 | 151 | 154 | 22.2 | 0.66 |
| | 800 | 8 | 1.10 | 159 | 170 | 24.6 | 0.66 |
| | | 10 | 0.98 | 141 | 151 | 21.8 | 0.64 |
| Coated Nextel 440 | 23 | 1 | 1.17 | 170 | 135 | 19.5 | 0.63 |
| | | 2 | 1.24 | 180 | 143 | 20.7 | 0.87 |
| | | 4 | 1.13 | 164 | 146 | 21.2 | 0.74 |
| | 500 | 8 | 0.64 | 93 | 144 | 20.9 | 0.42 |
| | | 10 | 0.83 | 120 | 142 | 20.5 | 0.55 |
| | 600 | 8 | 0.67 | 98 | 159 | 23.1 | 0.43 |
| | | 10 | 0.78 | 113 | 146 | 21.1 | 0.51 |
| | 700 | 8 | 0.79 | 115 | 153 | 22.2 | 0.52 |
| | | 10 | 0.70 | 102 | 145 | 21.0 | 0.50 |
| | 800 | 8 | 0.85 | 123 | 137 | 19.9 | 0.58 |
| | | 10 | 0.85 | 123 | 151 | 21.9 | 0.59 |
| Coated Nextel 480 | 23 | 1 | 1.25 | 181 | 176 | 25.5 | 0.61 |
| | | 2 | 0.99 | 144 | 160 | 23.2 | 0.62 |
| | | 4 | 1.24 | 179 | 209 | 30.3 | 0.55 |
| | 500 | 8 | 0.92 | 134 | 197 | 28.4 | 0.52 |
| | | 10 | 0.83 | 121 | 194 | 28.1 | 0.44 |
| | 600 | 8 | 0.91 | 131 | 161 | 23.3 | 0.56 |
| | | 10 | 0.85 | 123 | 196 | 28.4 | 0.41 |
| | 700 | 8 | 1.06 | 154 | 244 | 35.4 | 0.41 |
| | | 10 | 0.92 | 133 | 202 | 29.3 | 0.45 |
| | 800 | 8 | 1.04 | 151 | 177 | 25.7 | 0.54 |
| | | 10 | 1.06 | 153 | 199 | 28.8 | 0.57 |

Table 5 (Continued)

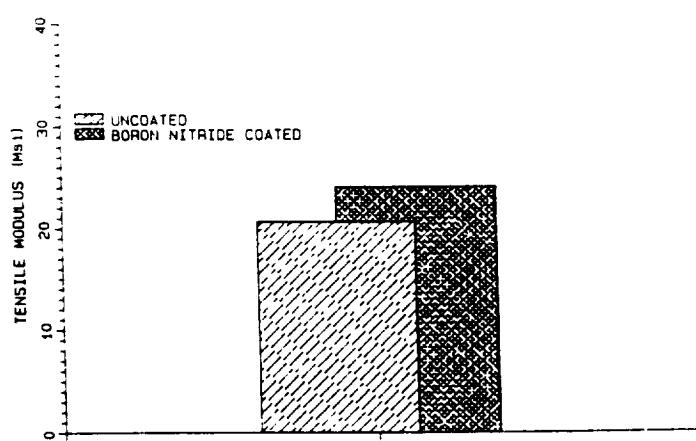
Average Static Tensile Data for Single
Boron Nitride Coated Fibers

| Fiber Type | Test Temp. (°C) | Gage Length (in.) | Tensile Strength (GPa) | Tensile Modulus (GPa) | Ultimate Strain (Msi) | Ultimate Strain (percent) | |
|---------------------------|--------------------|----------------------|---------------------------|--------------------------|--------------------------|------------------------------|------|
| Coated Nicalon NLM-102 | 23 | 1 | 1.98 | 287 | 128 | 18.6 | 1.52 |
| | | 2 | 2.93 | 424 | 210 | 30.4 | 1.41 |
| | | 4 | 2.15 | 311 | 183 | 26.6 | 1.26 |
| | 500 | 8 | 0.90 | 130 | 85 | 12.3 | 1.03 |
| | | 10 | 1.87 | 270 | 192 | 27.8 | 0.95 |
| | 600 | 8 | 1.54 | 223 | 171 | 24.8 | 0.88 |
| | | 10 | 1.66 | 241 | 166 | 24.0 | 1.03 |
| | 700 | 8 | 2.16 | 313 | 186 | 26.9 | 1.10 |
| | | 10 | 1.63 | 236 | 193 | 27.9 | 0.87 |
| | 800 | 8 | 1.40 | 203 | 138 | 20.0 | 0.94 |
| | | 10 | 2.04 | 296 | 216 | 31.3 | 0.96 |

NEXTEL 312 500 DEG C



NEXTEL 312 500 DEG C



NEXTEL 312 500 DEG C

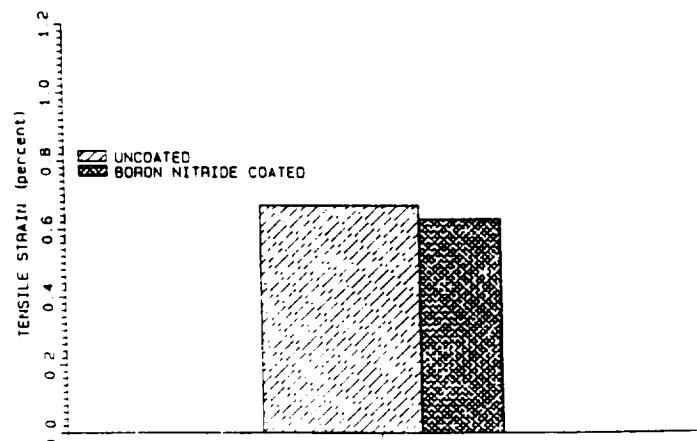
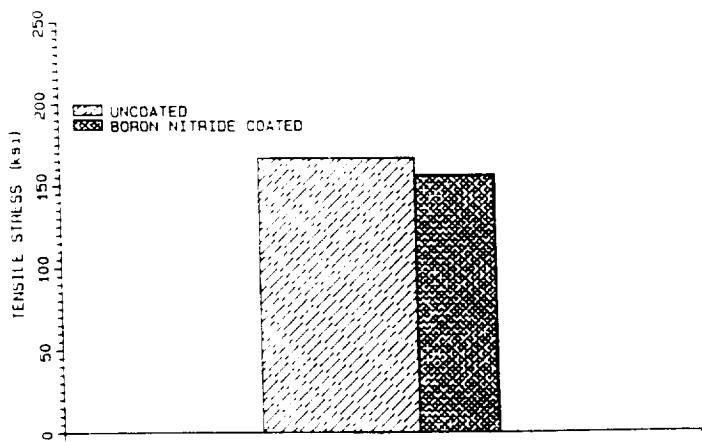
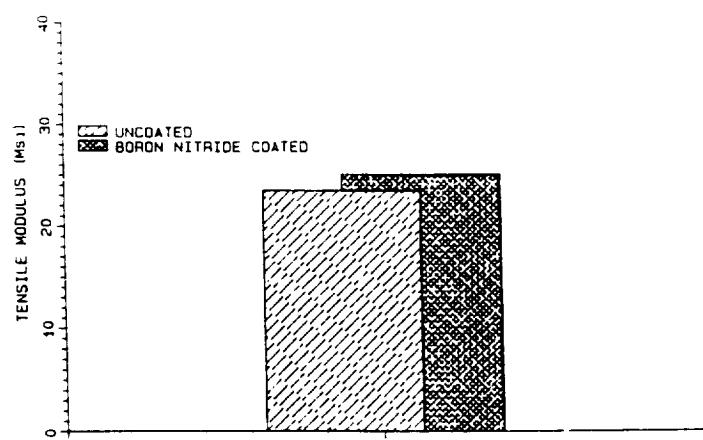


Figure 10. Comparison of Coated and Uncoated Nextel 312 Tensile Properties at 500°C.

NEXTEL 312 600 DEG C



NEXTEL 312 600 DEG C



NEXTEL 312 600 DEG C

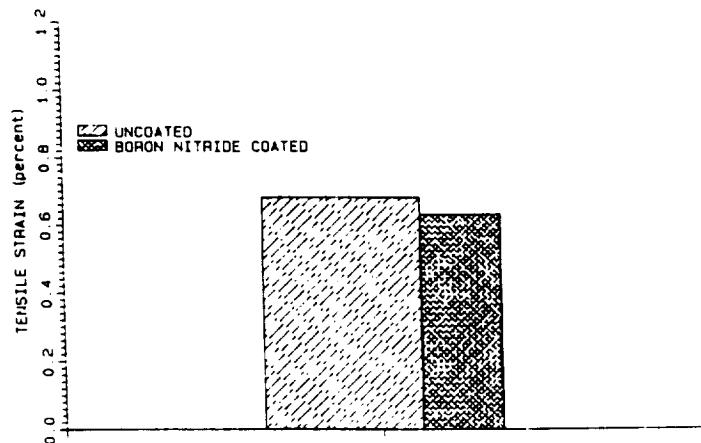
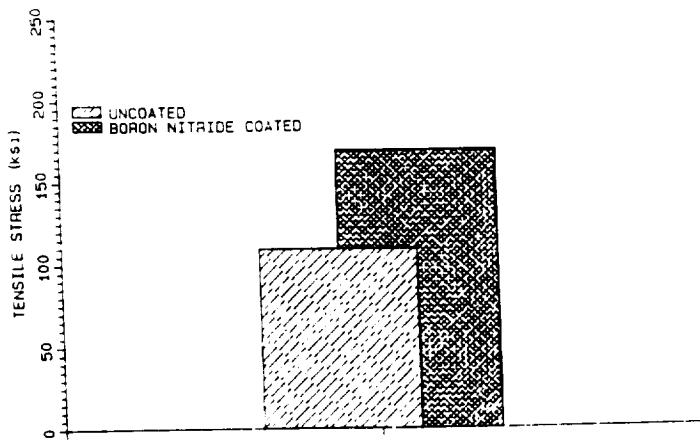
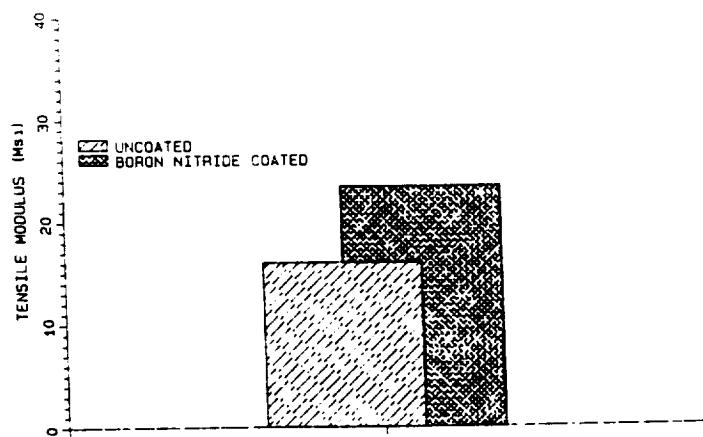


Figure 11. Comparison of Coated and Uncoated Nextel 312 Tensile Properties at 600°C.

NEXTEL 312 700 DEG C



NEXTEL 312 700 DEG C



NEXTEL 312 700 DEG C

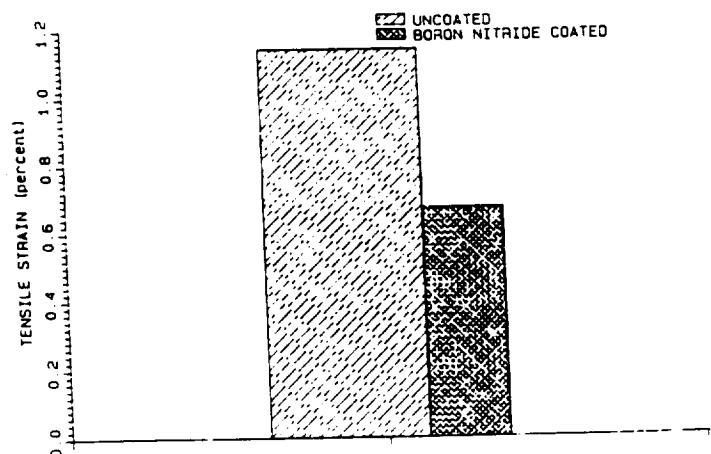
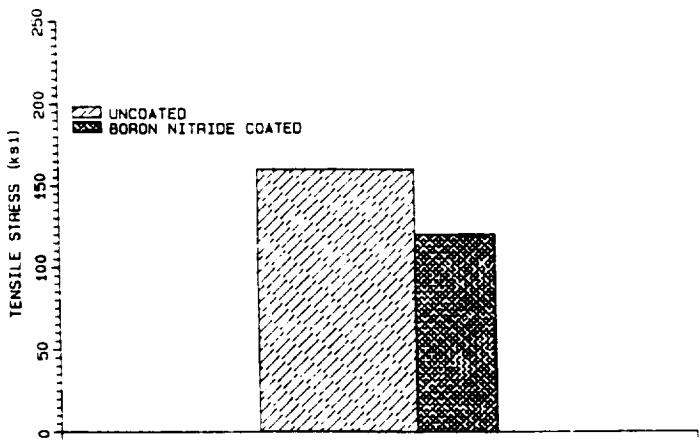
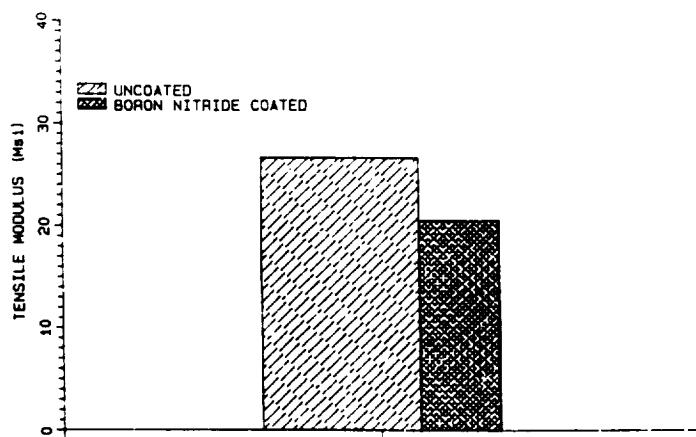


Figure 12. Comparison of Coated and Uncoated Nextel 312 Tensile Properties at 700°C.

NEXTEL 440 500 DEG C



NEXTEL 440 500 DEG C



NEXTEL 440 500 DEG C

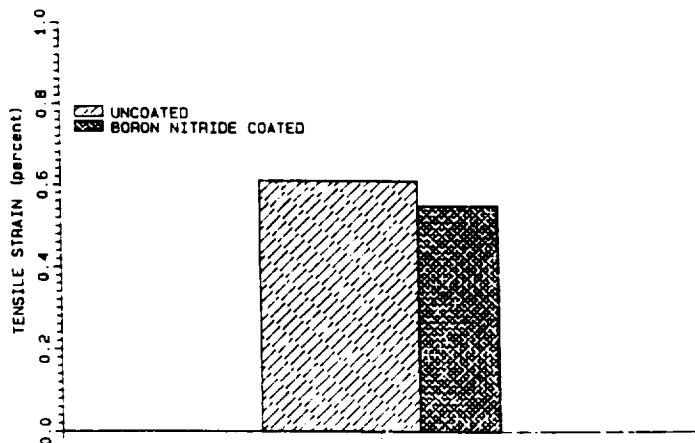
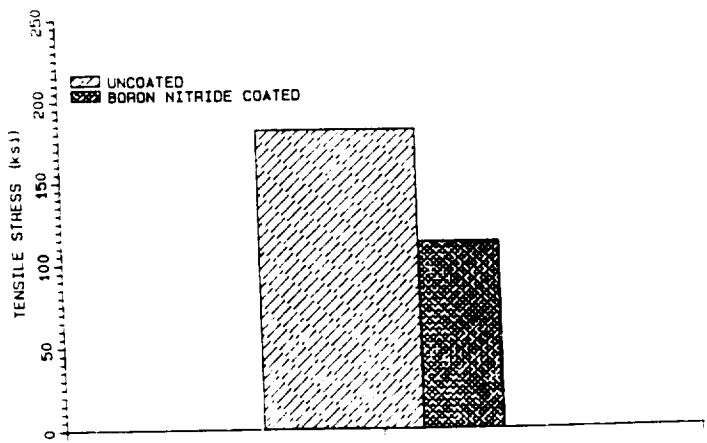
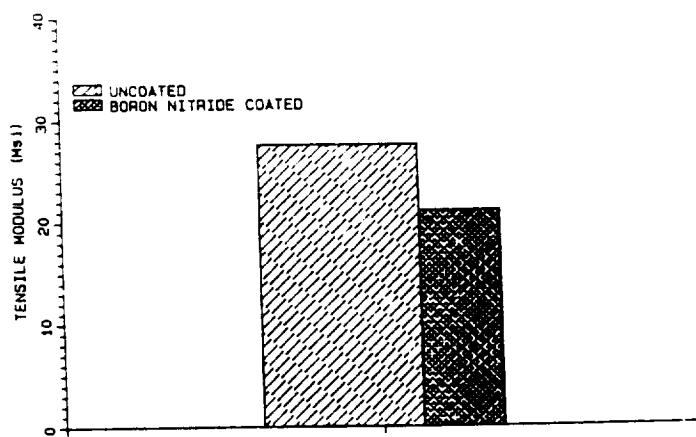


Figure 13. Comparison of Coated and Uncoated Nextel 440 Tensile Properties at 500°C.

NEXTEL 440 600 DEG C



NEXTEL 440 600 DEG C



NEXTEL 440 600 DEG C

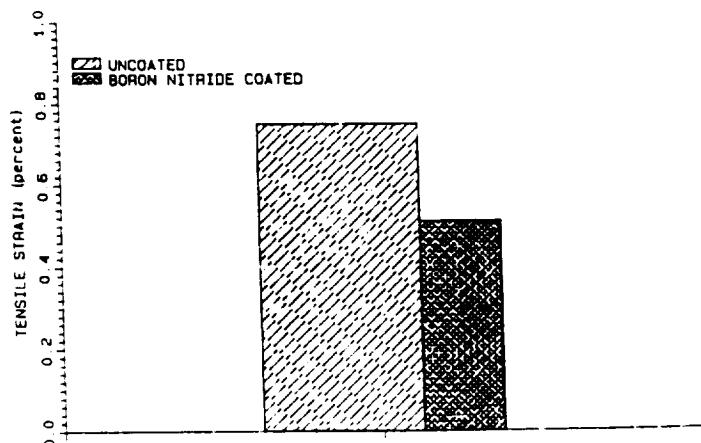
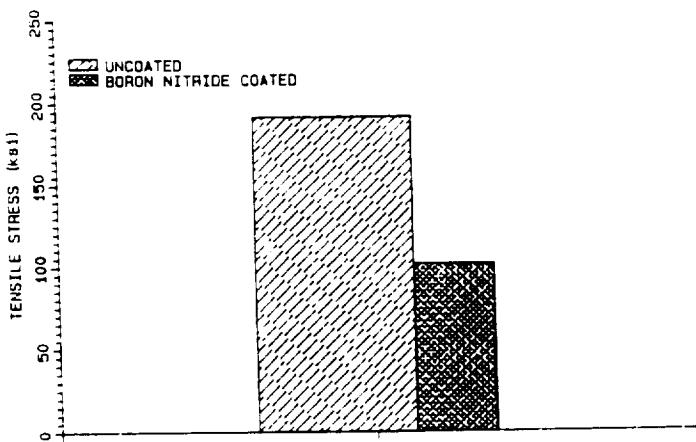
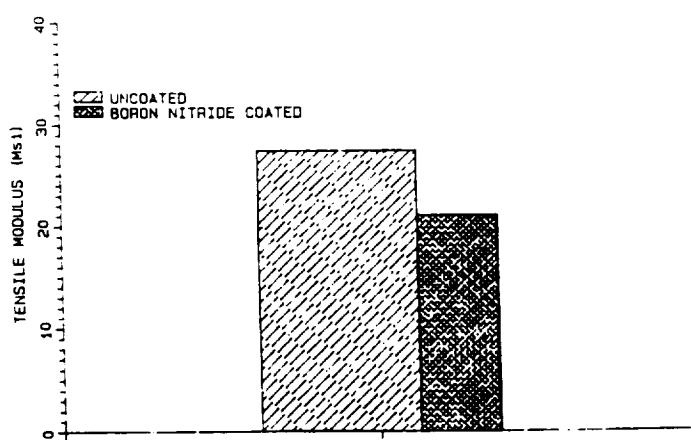


Figure 14. Comparison of Coated and Uncoated Nextel 440 Tensile Properties at 600°C.

NEXTEL 440 700 DEG C



NEXTEL 440 700 DEG C



NEXTEL 440 700 DEG C

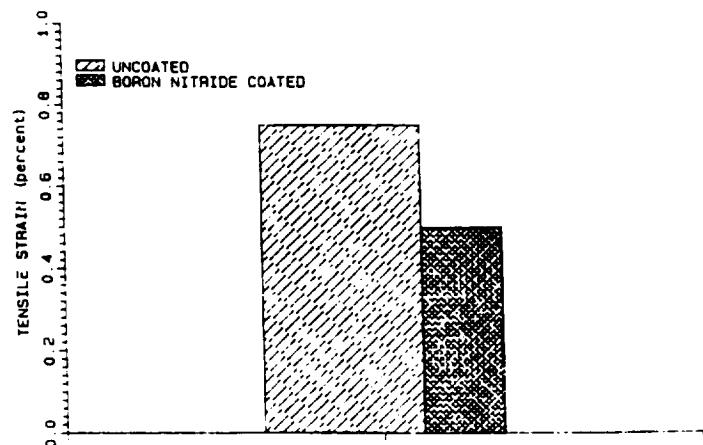
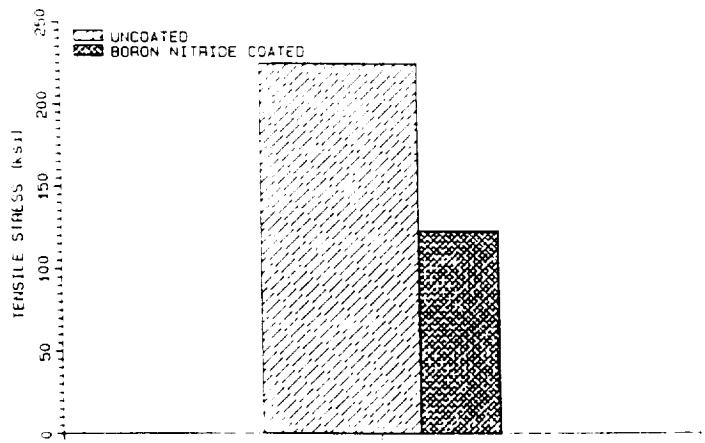
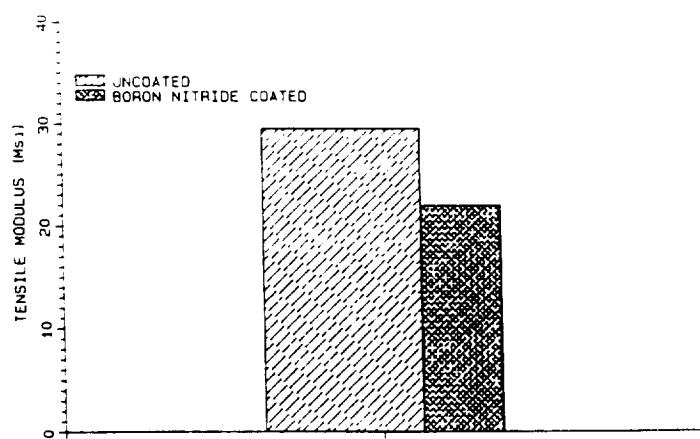


Figure 15. Comparison of Coated and Uncoated Nextel 440 Tensile Properties at 700°C.

NEXTEL 440 800 DEG C



NEXTEL 440 800 DEG C



NEXTEL 440 800 DEG C

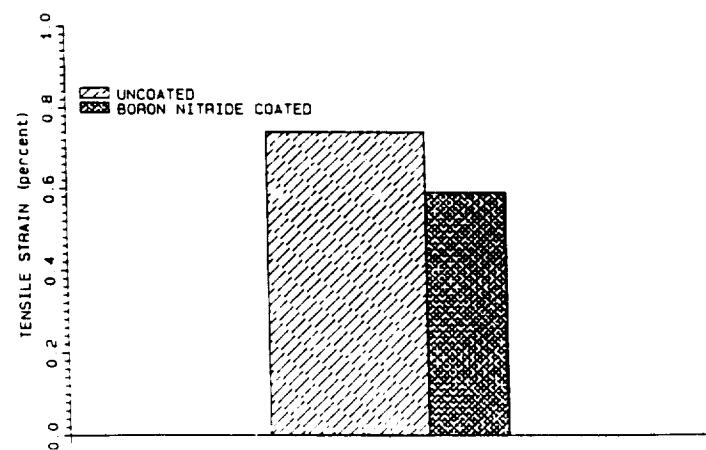


Figure 16. Comparison of Coated and Uncoated Nextel 440 Tensile Properties at 800°C.

appeared to lower static tensile results for the Nextel 440 fiber. A lack of improvement by the coating was also indicated by the strength trends when comparing the other coated to uncoated fibers.

3.3 Creep Test Results

Table 6 presents the average creep rates calculated after $\frac{1}{2}$ hour at each of the four elevated test temperatures each type of fiber was tested at. It will be noted that the four elevated test temperatures used for the creep testing of the five types of ceramic fibers were the same as those used for the static tensile testing of each type of fiber. Creep testing was performed only on the boron nitride coated fibers and on the Nextel 440 ceramic fiber.

A typical strain versus time curve generated from the creep testing is presented in Figure 17, to illustrate the creep response observed for the ceramic fibers tested in the present study. The remainder of the creep curves are included in Appendix B. All fibers were loaded to a slightly different percent of the static ultimate stresses measured at the four elevated test temperatures given in Table 5. The creep stress levels used here were somewhat lower than those of Reference [2]. The stress levels used were the highest the fibers could withstand. The boron nitride coating weakened the fibers. Lower creep stresses were necessary to prevent premature fiber failure when loading the fiber into the creep fixture. Each creep test was terminated after four hours; recovery strain was not monitored.

The creep rates presented here (Table 6) were calculated using two discrete time intervals. Creep rates were calculated using a linear regression technique to calculate the slopes between the two time

Table 6

Average Creep Rates for Five Types of Ceramic Fibers Tested

| Fiber Type | Test Temperature (°C) | Applied Stress* (ksi) | Strain Rate from $\frac{1}{2}$ Hour to 1 Hour ($10^{-6}/\text{hour}$) | Strain Rate from $\frac{1}{2}$ Hour to End of Test** ($10^{-6}/\text{hour}$) |
|--------------------------------------|-----------------------|-----------------------|---|--|
| <u>Uncoated Nextel 440</u> | | | | |
| | 500 | 80 | 524 | 52 |
| | 600 | | 223 | 50 |
| | 700 | | 54 | 190 |
| | 800 | | 539 | 334 |
| <u>Boron Nitride Nextel 312</u> | | | | |
| | 500 | 64 | 513 | 77 |
| | 600 | | 454 | 110 |
| | 700 | | 630 | 161 |
| | 800 | | 646 | 188 |
| <u>Boron Nitride Nextel 440</u> | | | | |
| | 500 | 60 | 173 | 42 |
| | 600 | | 280 | 80 |
| | 700 | | 593 | 104 |
| | 800 | | 434 | 122 |
| <u>Boron Nitride Nextel 480</u> | | | | |
| | 500 | 60 | 279 | 53 |
| | 600 | | 280 | 60 |
| | 700 | | 206 | 63 |
| | 800 | | 437 | 91 |
| <u>Boron Nitride Nicolon NLM-102</u> | | | | |
| | 500 | 136 | 878 | 235 |
| | 600 | | 525 | 224 |
| | 700 | | 447 | 92 |
| | 800 | | 475 | 114 |

* Creep stresses were at least 40 percent of ultimate stress at highest test temperature.

**Typically four hours.

DT5801.CRP

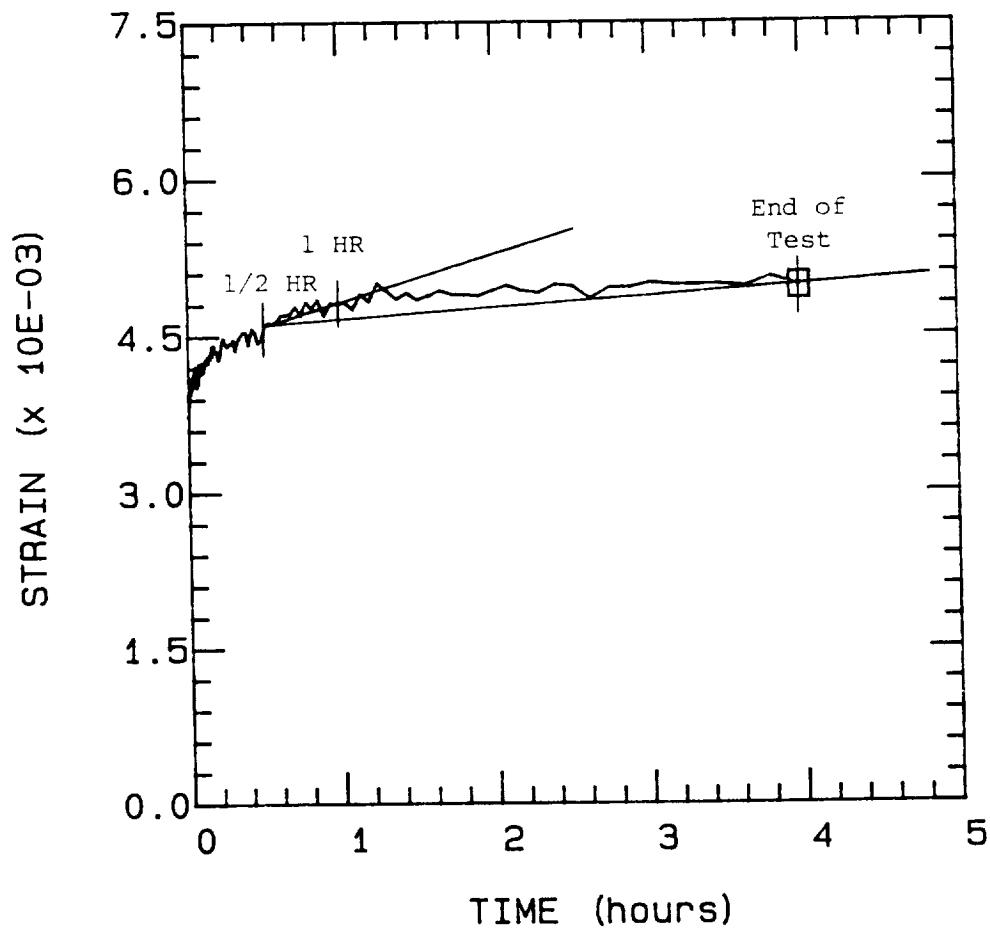


Figure 17. Typical Strain vs. Time Creep Plot Showing Two Creep Strain Rates.

intervals. One time interval was between $\frac{1}{2}$ hour and 1 hour elapsed time at the beginning of each creep test. The second interval was between $\frac{1}{2}$ hour and the end of each test, typically 3 to 4 hours total creep duration. Figure 17 illustrates the slopes calculated from the strain versus time curves. The earlier time interval yields a higher creep rate, as expected, and noted in Table 6 and Figure 17.

SECTION 4

CONCLUSIONS

The six uncoated ceramic fibers tested exhibited reasonable static mechanical properties over a wide temperature range from room temperature up to 1300°C. The results were very similar to those obtained in Reference [2]. Each fiber was tested over different temperature ranges consistent with their individual capabilities. Four of the fiber types previously tested were supplied in a boron nitride coated form. These four coated fibers exhibited different static mechanical properties than their uncoated forms. The coated fibers were tested at lower test temperatures than most of the uncoated fibers. Creep testing was performed on one of the uncoated fibers and four fiber types coated with boron nitride. Creep test temperatures were the same as those used in the static tensile tests of coated fibers.

These ceramic fibers are extremely brittle, which contributed to the data scatter seen in some of the reported data. Strength properties were most affected, with high standard deviations seen in the data. Variations in cross-sectional area of the fibers also contributed to the scatter.

The boron nitride coating only seemed to improve the performance of the Nextel 312 fiber. Testing of the other coated fibers resulted in similar or lower test values when compared to their uncoated counterparts.

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Appendix A
Individual Single Fiber Static Tensile Test Data

Table A1

Individual Single Fiber Tensile Test Data for
Astroquartz 9288 at Room Temperature

| Specimen No. | Fiber Area | | Tensile Strength | | Tensile Modulus | Ult. Strain | |
|-----------------------|---|------|------------------|---------------|-----------------|-------------|--------------|
| | (μm^2) (10^{-7} in^2) | | (GPa) | (ksi) | (GPa) | (Msi) | (percent) |
| 1" Gage Length | | | | | | | |
| ONA111 | 60.13 | 0.93 | 0.63 | 91.7* | 72.0 | 10.4 | 0.89* |
| 2 | | | 0.73 | 106.2 | 83.2 | 12.1* | 0.92* |
| 3 | | | 1.23 | 178.6* | 80.7 | 11.7 | 1.50* |
| 4 | | | 0.70 | 101.4 | 66.9 | 9.7 | 1.10 |
| 5 | | | 0.85 | 123.1 | 75.8 | 11.0 | 1.10 |
| 6 | | | 1.17 | 169.0* | 88.7 | 12.9* | 1.37 |
| 7 | | | 0.73 | 106.2 | 62.6 | 9.1* | 1.12 |
| 8 | | | 0.87 | 126.7 | 67.2 | 9.7 | 1.33 |
| 9 | | | 0.97 | 141.2 | 69.1 | 10.0 | 1.45* |
| 10 | | | <u>1.13</u> | <u>164.2*</u> | <u>73.4</u> | <u>10.6</u> | <u>1.29</u> |
| Average | 60.13 | 0.93 | 0.81 | 117.5 | 72.2 | 10.5 | 1.22 |
| Std. Dev. | 0 | 0 | 0.11 | 15.4 | 5.0 | 0.7 | 0.13 |
| 2" Gage Length | | | | | | | |
| ONA221 | 60.13 | 0.93 | 0.77 | 111.1 | 73.3 | 10.6 | 1.01 |
| 2 | | | 0.82 | 119.5 | 68.2 | 9.9* | 1.26* |
| 3 | | | 0.95 | 137.6* | 70.9 | 10.3 | 1.22 |
| 4 | | | 0.69 | 99.5 | 73.8 | 10.7 | 0.95 |
| 5 | | | 0.68 | 99.0 | 78.5 | 11.4* | 0.87* |
| 6 | | | 0.93 | 135.2* | 76.4 | 11.5* | 1.15 |
| 7 | | | 0.85 | 123.1 | 66.0 | 9.6* | 1.28 |
| 8 | | | 0.85 | 123.1 | 73.3 | 10.6 | 1.14 |
| 9 | | | 0.61 | 88.4* | 71.7 | 10.4 | 0.84* |
| 10 | | | <u>0.64</u> | <u>92.9*</u> | <u>77.1</u> | <u>11.2</u> | <u>0.85*</u> |
| Average | 60.13 | 0.93 | 0.78 | 112.5 | 73.3 | 10.6 | 1.10 |
| Std. Dev. | 0 | 0 | 0.08 | 11.2 | 2.1 | 0.3 | 0.11 |
| 4" Gage Length | | | | | | | |
| ONA141 | 60.13 | 0.93 | 0.58 | 84.0* | 75.8 | 11.0 | 0.76 |
| 2 | | | 0.74 | 107.7 | 78.8 | 11.4 | 0.96* |
| 3 | | | 0.67 | 97.0 | 78.5 | 11.4 | 0.86 |
| 4 | | | 0.51 | 73.9* | 76.1 | 11.0 | 0.66* |
| 5 | | | 0.70 | 101.4 | 72.1 | 10.5* | 0.98* |
| 6 | | | 0.77 | 111.1* | 84.9 | 12.3* | 0.90 |
| 7 | | | 0.63 | 91.7 | 81.8 | 11.9 | 0.78 |
| 8 | | | 0.70 | 101.4 | 79.0 | 11.5 | 0.88 |
| 10 | | | <u>0.73</u> | <u>106.2</u> | <u>80.6</u> | <u>11.7</u> | <u>0.91</u> |
| Average | 60.13 | 0.93 | 0.70 | 100.9 | 78.6 | 11.4 | 0.85 |
| Std. Dev. | 0 | 0 | 0.04 | 5.9 | 2.2 | 0.3 | 0.06 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A2

Individual Single Fiber Tensile Test Data for
Astroquartz 9288 at Elevated Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 500°C, 8" Gage Length | | | | | | | |
| 5NA181 | 60.13 | 0.93 | 1.36 | 197.0 | 84.5 | 12.3 | 1.61 |
| 2 | | | 1.76 | 254.9* | 84.9 | 12.3 | 2.06* |
| 3 | | | 0.77 | 111.5 | 72.9 | 10.6 | 1.09 |
| 4 | | | 0.89 | 128.4 | 77.8 | 11.3 | 1.13 |
| Average | 60.13 | 0.93 | 1.19 | 145.7 | 80.1 | 11.6 | 1.28 |
| Std. Dev. | 0 | 0 | 0.31 | 45.3 | 5.8 | 0.8 | 0.29 |
| 500°C, 10" Gage Length | | | | | | | |
| 5NA1101 | 60.13 | 0.93 | 1.64 | 237.1 | 84.2 | 12.2 | 1.93* |
| 2 | | | 1.33 | 193.1 | 89.8 | 13.0* | 1.45* |
| 3 | | | 1.27 | 184.0* | 84.5 | 12.2 | 1.50 |
| 4 | | | 1.58 | 229.3 | 82.7 | 12.0* | 1.83 |
| 5 | | | 1.57 | 226.9 | 89.5 | 13.0* | 1.74 |
| Average | 60.13 | 0.93 | 1.53 | 221.6 | 84.3 | 12.2 | 1.69 |
| Std. Dev. | 0 | 0 | 0.13 | 19.5 | 0.1 | 0.0 | 0.17 |
| 600°C, 8" Gage Length | | | | | | | |
| 6NA181 | 60.13 | 0.93 | 1.54 | 222.6* | 77.7 | 11.3* | 1.96* |
| 2 | | | 1.13 | 163.2 | 68.9 | 10.0 | 1.60 |
| 3 | | | 1.08 | 156.9 | 70.5 | 10.2 | 1.49 |
| 4 | | | 1.18 | 170.4 | 74.0 | 10.7 | 1.57 |
| 5 | | | 0.76 | 110.1* | 70.4 | 10.2 | 1.07* |
| Average | 60.13 | 0.93 | 1.13 | 163.5 | 71.0 | 10.3 | 1.55 |
| Std. Dev. | 0 | 0 | 0.05 | 6.8 | 2.2 | 0.3 | 0.06 |
| 700°C, 8" Gage Length | | | | | | | |
| 7NA181 | 60.13 | 0.93 | 1.10 | 159.1 | 75.3 | 10.9 | 1.44 |
| 2 | | | 0.68 | 98.0* | 69.8 | 10.1 | 1.02* |
| 3 | | | 1.09 | 157.9 | 74.7 | 10.8 | 1.47 |
| 4 | | | 1.06 | 153.3 | 75.3 | 10.9 | 1.39 |
| 5 | | | 1.19 | 172.1* | 71.9 | 10.4 | 1.70* |
| 6 | | | 0.84 | 121.4 | 67.7 | 9.8* | 1.25 |
| Average | 60.13 | 0.93 | 1.02 | 147.9 | 73.4 | 10.6 | 1.39 |
| Std. Dev. | 0 | 0 | 0.12 | 17.8 | 2.2 | 0.3 | 0.10 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A2
(Continued)

| Specimen No. | Fiber Area (μm^2) | (10^{-7} in 2) | Tensile Strength (GPa) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|------------------------------|-----------------------------------|-----------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 800°C, 8" Gage Length | | | | | | |
| 8NA181 | 60.13 | 0.93 | 0.75 | 108.6 | 73.3 | 10.6 |
| 2 | | | 0.93 | 134.2* | 72.0 | 10.4 |
| 3 | | | 0.79 | 114.9 | 60.8 | 8.8 |
| 4 | | | 0.69 | 99.7* | 71.9 | 10.4 |
| 5 | | | 0.84 | 121.4 | 57.3 | 8.3* |
| Average | 60.13 | 0.93 | 0.79 | 115.0 | 69.5 | 10.1 |
| Std. Dev. | 0 | 0 | 0.04 | 6.4 | 5.8 | 0.8 |
| | | | | | | 0.11 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A3

Individual Single Fiber Tensile Test Data for Uncoated
Nicalon NLM-102 at Room Temperature

| Specimen No. | Fiber Area (μm^2) | (10^{-7} in^2) | Tensile Strength (GPa) | (ksi) | Tensile Modulus (GPa) | (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|---------------------------|------------------------------|--------------|-----------------------------|-------------|---------------------------------|
| 1" Gage Length | | | | | | | |
| 0NA211C | 149.57 | 2.32 | 2.37 | 344.0 | 211.9 | 30.7 | 1.07 |
| 2C | | | 3.16 | 458.0* | 240.2 | 34.8 | 1.33* |
| 5C | | | 2.32 | 335.8 | 214.0 | 31.0 | 1.09 |
| 7C | | | 2.17 | 314.5 | 203.3 | 29.5* | 1.06 |
| 9C | | | 2.00 | 289.2* | 253.0 | 36.7* | 1.07 |
| 10C | | | 2.41 | 349.4 | 227.1 | 32.9 | 1.14 |
| Average | 149.57 | 2.32 | 2.32 | 335.9 | 223.3 | 32.4 | 1.08 |
| Std. Dev. | 0 | 0 | 0.11 | 15.4 | 13.1 | 1.9 | 0.03 |
| 2" Gage Length | | | | | | | |
| 0NA222C | 149.57 | 2.32 | 2.42 | 351.2* | 174.6 | 25.3* | 1.38 |
| 3C | | | 3.13 | 454.1* | 325.3 | 47.2* | 0.97* |
| 4C | | | 2.97 | 430.9 | 302.9 | 43.9* | 0.98* |
| 5C | | | 2.52 | 365.2* | 190.4 | 27.6 | 1.32 |
| 6C | | | 2.80 | 405.8 | 204.8 | 29.7 | 1.35 |
| 7C | | | 2.97 | 430.0 | 211.9 | 30.7 | 1.39 |
| 8C | | | 2.78 | 402.4 | 235.7 | 34.2 | 1.19 |
| Average | 149.57 | 2.32 | 2.88 | 417.3 | 210.7 | 30.5 | 1.32 |
| Std. Dev. | 0 | 0 | 0.11 | 15.3 | 18.9 | 2.7 | 0.08 |
| 4" Gage Length | | | | | | | |
| 0NA241C | 149.57 | 2.32 | 2.06 | 299.0 | 202.3 | 29.3* | 0.98 |
| 2C | | | 2.24 | 324.6 | 223.8 | 32.4* | 1.00 |
| 3C | | | 2.59 | 375.4 | 249.9 | 36.2 | 1.04 |
| 4C | | | 2.07 | 300.5 | 264.6 | 38.4 | 0.78 |
| 5C | | | 3.14 | 454.6* | 315.3 | 45.7* | 0.99 |
| 6C | | | 3.37 | 487.9* | 335.8 | 48.7* | 1.00 |
| 8C | | | 1.64 | 238.2* | 250.7 | 36.3 | 0.65* |
| 9C | | | 3.08 | 445.9 | 308.4 | 44.7 | 1.00 |
| 10C | | | 2.25 | 326.6 | 284.9 | 41.3 | 0.78 |
| Average | 149.57 | 2.32 | 2.38 | 345.3 | 271.7 | 39.4 | 0.95 |
| Std. Dev. | 0 | 0 | 0.39 | 56.5 | 24.9 | 3.6 | 0.10 |

* Numbers not used in calculating Average and Standard Deviation.

Table A4

Individual Single Fiber Tensile Test Data for Uncoated
Nicalon NLM-102 at Elevated Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|--------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 1000°C, 8" Gage Length | | | | | | | |
| ONA281 | 149.57 | 2.32 | 1.87 | 271.0 | 277.2 | 40.2* | 0.67 |
| 2 | | | 1.76 | 254.5 | 247.6 | 35.9 | 0.70 |
| 3 | | | 1.88 | 273.0 | 228.1 | 33.1 | 0.79 |
| 4 | | | 2.08 | 301.1* | 271.8 | 39.4 | 0.77 |
| 5 | | | 1.43 | 206.5* | 253.0 | 36.7 | 0.56* |
| 6 | | | 1.80 | 261.3 | 223.0 | 32.3* | 0.80 |
| Average | 149.57 | 2.32 | 1.83 | 265.0 | 250.2 | 36.3 | 0.75 |
| Std. Dev. | 0 | 0 | 0.06 | 8.6 | 18.0 | 2.6 | .06 |
| 1000°C, 10" Gage Length | | | | | | | |
| ONA101 | 149.57 | 2.32 | 1.51 | 218.7 | 201.3 | 29.2 | 0.74 |
| 2 | | | 1.42 | 206.1 | 221.4 | 32.1 | 0.63 |
| 3 | | | 0.99 | 143.5* | 207.1 | 30.0 | 0.48* |
| 4 | | | 1.84 | 266.7* | 262.8 | 38.1* | 0.70 |
| 5 | | | 1.76 | 254.5 | 235.1 | 34.1 | 0.73 |
| 6 | | | 1.37 | 198.3 | 197.7 | 28.7 | 0.68 |
| Average | 149.57 | 2.32 | 1.51 | 219.4 | 212.5 | 30.8 | 0.70 |
| Std. Dev. | 0 | 0 | 0.17 | 24.9 | 15.5 | 2.2 | 0.04 |
| 1100°C, 8" Gage Length | | | | | | | |
| 1NA281A | 149.57 | 2.32 | 1.76 | 255.0 | 214.1 | 31.0 | 0.82 |
| 2A | | | 1.34 | 194.4* | 171.8 | 24.9* | 0.79 |
| 3A | | | 2.42 | 351.0 | 255.9 | 37.1 | 0.95 |
| 4A | | | 1.54 | 223.0 | 212.2 | 30.8 | 0.73* |
| 5A | | | 2.61 | 378.7* | 270.8 | 39.2* | 0.96* |
| Average | 149.57 | 2.32 | 1.91 | 276.4 | 227.4 | 33.0 | 0.85 |
| Std. Dev. | 0 | 0 | 0.46 | 66.6 | 24.7 | 3.6 | 0.09 |
| 1200°C, 8" Gage Length | | | | | | | |
| 2NA281 | 149.57 | 2.32 | 1.49 | 215.3 | 145.0 | 21.0 | 1.04 |
| 2 | | | 1.02 | 148.4* | 101.4 | 14.7* | 1.02 |
| 3 | | | 1.49 | 215.3 | 115.0 | 16.7* | 1.29* |
| 4 | | | 1.40 | 203.1 | 155.7 | 22.6 | 0.92 |
| 5 | | | 1.82 | 263.8 | 223.0 | 32.3* | 0.81* |
| 6 | | | 1.59 | 230.3 | 205.9 | 29.8 | 0.78* |
| 7 | | | 2.64 | 383.0* | 234.3 | 34.0* | 1.12 |
| Average | 149.57 | 2.32 | 1.56 | 225.5 | 168.8 | 24.5 | 1.02 |
| Std. Dev. | 0 | 0 | 0.16 | 23.4 | 32.5 | 4.7 | 0.08 |

* Numbers not used in calculating Average and Standard Deviation.

Table A4

(Continued)

| Specimen No. | Fiber Area (μm^2) | (10^{-7} in^2) | Tensile Strength (GPa) | (ksi) | Tensile Modulus (GPa) | (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---------------------------|------------------------------|--------------|-----------------------------|-------------|---------------------------------|
| 1300°C, 8" Gage Length | | | | | | | |
| 3NA281 | 149.57 | 2.32 | 1.02 | 148.4 | 136.4 | 19.8* | 0.77 |
| 2 | | | 1.20 | 174.5 | 171.8 | 24.9 | 0.70 |
| 3 | | | 1.61 | 233.2 | 147.1 | 21.3 | 1.12* |
| 4 | | | 2.05 | 297.2* | 220.9 | 32.0* | 0.94 |
| 5 | | | 0.81 | 116.8* | 172.6 | 25.0 | 0.44* |
| Average | 149.57 | 2.32 | 1.28 | 185.4 | 163.9 | 23.7 | 0.80 |
| Std. Dev. | 0 | 0 | 0.30 | 43.4 | 14.5 | 2.1 | 0.12 |

* Numbers not used in calculating Average and Standard Deviation.

Table A5

Individual Single Fiber Tensile Test Data for
Nextel 312 at Room Temperature

| Specimen No. | Fiber Area (μm^2) | (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|---------------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 1" Gage Length | | | | | | | |
| 031211 | 84.83 | 1.31 | 1.23 | 178.2 | 103.4 | 15.0 | 1.19 |
| 2 | | | 1.17 | 169.5 | 110.1 | 16.0 | 1.06 |
| 3 | | | 1.45 | 210.4 | 102.9 | 14.9 | 1.40 |
| 4 | | | 1.33 | 193.4 | 105.4 | 15.3 | 1.37 |
| 5 | | | 0.92 | 133.1* | 105.7 | 15.3 | 0.89* |
| 6 | | | 1.26 | 182.0 | 109.1 | 15.8 | 1.13 |
| 7 | | | 1.39 | 200.9 | 109.1 | 15.8 | 1.27 |
| 8 | | | 1.62 | 235.1* | 111.6 | 16.2* | 1.44 |
| 9 | | | 1.72 | 249.1* | 97.1 | 14.1* | 1.76* |
| 10 | | | 1.16 | 168.0 | 98.8 | 14.3* | 1.17 |
| Average | 84.83 | 1.31 | 1.28 | 186.0 | 106.5 | 15.4 | 1.25 |
| Std. Dev. | 0 | 0 | 0.11 | 16.1 | 2.9 | 0.4 | 0.14 |
| 2" Gage Length | | | | | | | |
| 131221 | 84.83 | 1.31 | 1.05 | 151.7 | 116.7 | 16.9 | 0.89 |
| 2 | | | 1.05 | 151.7 | 117.5 | 17.0 | 1.03 |
| 3 | | | 1.72 | 249.1* | 108.5 | 15.7 | 0.81* |
| 4 | | | 1.72 | 249.1* | 133.7 | 19.4* | 1.29* |
| 5 | | | 0.89 | 129.7 | 92.9 | 13.5* | 0.96 |
| 6 | | | 1.05 | 151.7 | 112.0 | 16.2 | 0.92 |
| 8 | | | 1.55 | 224.8 | 137.1 | 19.9* | 1.13 |
| 9 | | | 0.85 | 123.2 | 110.5 | 16.0 | 1.31* |
| 10 | | | 0.85 | 123.2 | 97.4 | 14.1* | 0.88 |
| Average | 84.83 | 1.31 | 1.04 | 150.8 | 113.0 | 16.4 | 0.97 |
| Std. Dev. | 0 | 0 | 0.24 | 35.2 | 3.9 | 0.6 | 0.10 |
| 4" Gage Length | | | | | | | |
| 031241C | 84.83 | 1.31 | 0.94 | 136.5 | 169.7 | 24.6* | 0.56 |
| 2C | | | 0.93 | 134.6 | 134.4 | 19.5 | 0.69 |
| 3C | | | 1.36 | 197.2* | 174.5 | 25.3* | 0.78 |
| 4C | | | 1.28 | 185.8* | 140.1 | 20.3 | 0.91* |
| 5C | | | 0.06 | 9.4* | 11.0 | 1.6* | 0.58 |
| 6C | | | 0.52 | 74.7 | 117.6 | 17.1 | 0.43* |
| 7C | | | 0.74 | 106.9 | 104.8 | 15.2 | 0.71 |
| 8C | | | 0.72 | 104.6 | 115.2 | 16.7 | 0.63 |
| 9C | | | 0.46 | 66.4 | 121.2 | 17.6 | 0.38* |
| 10C | | | 0.87 | 125.5 | 141.9 | 20.6 | 0.61 |
| Average | 84.83 | 1.31 | 0.74 | 107.0 | 125.0 | 18.1 | 0.65 |
| Std. Dev. | 0 | 0 | 0.19 | 27.9 | 14.0 | 2.0 | 0.08 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A6

Individual Single Fiber Tensile Test Data for
Nextel 312 at Elevated Temperature

| Specimen No. | Fiber Area (μm^2) | (10^{-7} in^2) | Tensile Strength (GPa) | (ksi) | Tensile Modulus (GPa) | (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---------------------------|------------------------------|--------|-----------------------------|-------|---------------------------------|
| 400°C, 8" Gage Length | | | | | | | |
| 431281 | 84.83 | 1.31 | 1.11 | 160.4 | 154.6 | 22.4 | 0.72 |
| 2 | | | 1.11 | 161.1 | 152.0 | 22.0 | 0.73 |
| 3 | | | 1.06 | 153.9 | 150.8 | 21.9 | 0.70 |
| 4 | | | 1.09 | 157.7 | 164.9 | 23.9* | 0.65 |
| 5 | | | 0.95 | 137.6* | 160.1 | 23.2 | 0.59* |
| Average | 84.83 | 1.31 | 1.09 | 158.3 | 154.3 | 22.4 | 0.70 |
| Std. Dev. | 0 | 0 | 0.02 | 3.3 | 4.1 | 0.6 | 0.04 |
| 500°C, 8" Gage Length | | | | | | | |
| 531281 | 84.83 | 1.31 | 0.86 | 124.4 | 143.9 | 20.9 | 0.59 |
| 2 | | | 0.89 | 129.3 | 153.3 | 22.2* | 0.58* |
| 3 | | | 0.95 | 137.6 | 142.5 | 20.7 | 0.70 |
| 4 | | | 0.93 | 135.0 | 135.4 | 19.6* | 0.70 |
| 5 | | | 0.98 | 142.2 | 139.5 | 20.2 | 0.69 |
| 6 | | | 1.28 | 185.0* | 152.8 | 22.2* | 0.84* |
| Average | 84.83 | 1.31 | 0.92 | 133.7 | 142.0 | 20.6 | 0.67 |
| Std. Dev. | 0 | 0 | 0.05 | 7.0 | 2.3 | 0.3 | 0.05 |
| 500°C, 10" Gage Length | | | | | | | |
| 5312101 | 84.83 | 1.31 | 1.28 | 186.2* | 202.4 | 29.3* | 0.62 |
| 2 | | | 0.70 | 101.6* | 137.7 | 20.0 | 0.50* |
| 3 | | | 0.98 | 142.2 | 147.9 | 21.4 | 0.66 |
| 4 | | | 1.08 | 156.6 | 145.9 | 21.2 | 0.72* |
| 5 | | | 0.83 | 121.0 | 130.3 | 18.9 | 0.63 |
| Average | 84.83 | 1.31 | 0.97 | 139.9 | 140.5 | 20.4 | 0.64 |
| Std. Dev. | 0 | 0 | 0.12 | 17.9 | 8.1 | 1.2 | 0.02 |
| 600°C, 8" Gage Length | | | | | | | |
| 631281 | 84.83 | 1.31 | 0.91 | 132.5* | 167.8 | 24.3 | 0.54* |
| 2 | | | 1.13 | 164.0 | 148.7 | 21.6 | 0.75* |
| 3 | | | 0.89 | 129.5* | 132.8 | 19.2* | 0.65 |
| 4 | | | 1.14 | 165.7 | 166.9 | 24.2 | 0.68 |
| 5 | | | 1.17 | 169.5 | 161.9 | 23.5 | 0.71 |
| Average | 84.83 | 1.31 | 1.15 | 166.4 | 161.4 | 23.4 | 0.68 |
| Std. Dev. | 0 | 0 | 0.02 | 2.8 | 8.8 | 1.3 | 0.02 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A6
(Continued)

| Specimen No. | Fiber Area (μm^2) | 10^{-7} in^2 | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|------------------------------|-----------------------------------|-----------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 700°C, 8" Gage Length | | | | | | | |
| 731281 | 84.83 | 1.31 | 0.56 | 81.3* | 103.1 | 14.9 | 1.27* |
| 2 | | | 0.79 | 114.3 | 127.7 | 18.5* | 1.18 |
| 3 | | | 0.75 | 108.8 | 111.5 | 16.2 | 1.12 |
| 4 | | | 0.86 | 125.1* | 116.7 | 16.9 | 0.92* |
| 5 | | | 0.72 | 104.3 | 86.4 | 12.5* | 1.12 |
| Average | 84.83 | 1.31 | 0.75 | 109.1 | 110.4 | 16.0 | 1.14 |
| Std. Dev. | 0 | 0 | 0.03 | 5.0 | 6.9 | 1.0 | 0.03 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A7

Individual Single Fiber Tensile Test Data for
Nextel 380 at Room Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 1" Gage Length | | | | | | | |
| 038011 | 94.17 | 1.68 | 2.12 | 308.4* | 143.2 | 20.8 | 1.49* |
| 2 | | | 1.23 | 179.6 | 128.8 | 18.7 | 0.98* |
| 3 | | | 1.11 | 160.2* | 87.8 | 12.7* | 1.26 |
| 4 | | | 1.52 | 221.0 | 122.8 | 17.8 | 1.22 |
| 5 | | | 2.00 | 290.0* | 143.6 | 20.8 | 1.38 |
| 6 | | | 1.41 | 204.9 | 135.1 | 19.6 | 1.05 |
| 8 | | | 1.12 | 162.2* | 129.7 | 18.8 | 0.86* |
| 9 | | | 1.64 | 237.0 | 142.1 | 20.6 | 1.13 |
| 10 | | | 1.68 | 244.2 | 127.0 | 18.4 | 1.31 |
| Average | 94.17 | 1.68 | 1.50 | 217.3 | 134.0 | 19.4 | 1.22 |
| Std. Dev. | 0 | 0 | 0.16 | 23.2 | 8.2 | 1.2 | 1.11 |
| 2" Gage Length | | | | | | | |
| 038021 | 94.17 | 1.68 | 1.03 | 148.9* | 127.6 | 18.5* | 0.81 |
| 2 | | | 1.59 | 230.5 | 153.6 | 22.3 | 1.03 |
| 3 | | | 1.30 | 187.8 | 130.0 | 18.8* | 1.00 |
| 4 | | | 1.48 | 213.8 | 163.4 | 23.7* | 0.91 |
| 5 | | | 1.62 | 235.3* | 146.6 | 21.3 | 1.10* |
| 6 | | | 0.91 | 131.5* | 152.1 | 22.0 | 0.60* |
| 7 | | | 1.74 | 251.7* | 149.8 | 21.7 | 1.16* |
| 8 | | | 1.00 | 145.2* | 151.7 | 22.0 | 0.62* |
| 9 | | | 1.34 | 194.0 | 153.2 | 22.2 | 0.87 |
| 10 | | | 1.26 | 182.0 | 135.0 | 19.6 | 0.93 |
| Average | 94.17 | 1.68 | 1.39 | 201.6 | 148.8 | 21.6 | 0.92 |
| Std. Dev. | 0 | 0 | 0.14 | 20.1 | 6.6 | 0.9 | 0.08 |
| 4" Gage Length | | | | | | | |
| 038041 | 94.17 | 1.68 | 0.94 | 136.6 | 137.0 | 19.9 | 0.68* |
| 2 | | | 1.13 | 163.9 | 127.5 | 18.5* | 0.88 |
| 3 | | | 0.78 | 113.4* | 132.5 | 19.2 | 0.60* |
| 4 | | | 1.10 | 159.2 | 135.0 | 19.6 | 0.80 |
| 5 | | | 1.56 | 225.4* | 147.5 | 21.4* | 1.05* |
| 6 | | | 1.14 | 165.6 | 132.8 | 19.3 | 0.85 |
| 7 | | | 1.47 | 213.1* | 154.0 | 22.3* | 0.95 |
| 8 | | | 1.21 | 175.9 | 142.0 | 20.6 | 0.85 |
| 9 | | | 1.05 | 152.3 | 130.4 | 18.9 | 0.80 |
| Average | 94.17 | 1.68 | 1.10 | 158.9 | 135.0 | 19.6 | 0.86 |
| Std. Dev. | 0 | 0 | 0.09 | 13.4 | 3.8 | 0.5 | 0.06 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A8

Individual Single Fiber Tensile Test Data for
Nextel 380 at Elevated Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 600°C, 8" Gage Length | | | | | | | |
| 638081 | 94.17 | 1.68 | 1.42 | 205.9 | 163.4 | 23.7 | 0.87 |
| 2 | | | 1.56 | 226.8 | 185.0 | 26.8* | 0.85 |
| 3 | | | 1.54 | 223.0 | 164.5 | 23.8 | 0.94* |
| 4 | | | 0.88 | 128.1* | 156.6 | 22.7 | 0.58* |
| 5 | | | 1.10 | 158.8 | 155.6 | 22.6 | 0.71 |
| Average | 94.17 | 1.68 | 1.40 | 203.6 | 160.0 | 23.2 | 0.81 |
| Std. Dev. | 0 | 0 | 0.22 | 31.2 | 4.4 | 0.7 | 0.07 |
| 600°C, 10" Gage Length | | | | | | | |
| 6380101 | 94.17 | 1.68 | 1.30 | 187.8* | 152.0 | 22.0 | 0.85 |
| 2 | | | 1.47 | 212.8* | 163.0 | 23.6 | 0.93* |
| 3 | | | 1.41 | 204.2 | 164.7 | 23.9 | 0.85 |
| 4 | | | 1.37 | 199.1 | 157.9 | 22.9 | 0.87 |
| 5 | | | 1.31 | 189.2 | 143.5 | 20.8* | 0.88 |
| Average | 94.17 | 1.68 | 1.36 | 197.5 | 159.4 | 23.1 | 0.86 |
| Std. Dev. | 0 | 0 | 0.05 | 7.6 | 5.7 | 0.8 | 0.02 |
| 700°C, 8" Gage Length | | | | | | | |
| 738081 | 94.17 | 1.68 | 1.72 | 249.0* | 180.2 | 26.1* | 0.96 |
| 2 | | | 1.13 | 163.9 | 145.5 | 21.1 | 0.79 |
| 3 | | | 1.53 | 221.3 | 148.6 | 21.5 | 1.01* |
| 4 | | | 1.35 | 196.0 | 138.1 | 20.0 | 0.95 |
| 5 | | | 1.02 | 148.2* | 133.2 | 19.3 | 0.75* |
| Average | 94.17 | 1.68 | 1.34 | 193.8 | 141.3 | 20.5 | 0.90 |
| Std. Dev. | 0 | 0 | 0.20 | 28.8 | 6.1 | 0.9 | 0.10 |
| 800°C, 8" Gage Length | | | | | | | |
| 838081 | 94.17 | 1.68 | 0.99 | 143.1* | 145.9 | 21.1* | 0.78 |
| 2 | | | 0.87 | 126.7 | 135.4 | 19.6 | 0.77 |
| 3 | | | 0.87 | 126.7 | 132.5 | 19.2 | 0.79 |
| 4 | | | 0.65 | 93.9* | 121.0 | 17.5* | 0.60* |
| 5 | | | 0.74 | 106.9 | 122.5 | 17.8 | 0.68 |
| 6 | | | 0.94 | 136.6 | 129.0 | 18.7 | 0.82 |
| Average | 94.17 | 1.68 | 0.86 | 124.2 | 129.9 | 18.8 | 0.77 |
| Std. Dev. | 0 | 0 | 0.09 | 12.5 | 4.8 | 0.7 | 0.05 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A8

(Continued)

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 900°C, 8" Gage Length | | | | | | | |
| 938081 | 94.17 | 1.68 | 1.02 | 147.9 | 124.4 | 18.0 | 0.91* |
| 2 | | | 0.77 | 111.7 | 129.0 | 18.7 | 0.62* |
| 3 | | | 0.90 | 130.3 | 144.1 | 20.9* | 0.75 |
| 4 | | | 1.08 | 156.9* | 132.5 | 19.2 | 0.83 |
| 5 | | | 0.75 | 109.3* | 122.5 | 17.8 | 0.64 |
| Average | 94.17 | 1.68 | 0.90 | 129.9 | 127.1 | 18.4 | 0.74 |
| Std. Dev. | 0 | 0 | 0.12 | 18.1 | 3.9 | 0.6 | 0.08 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A9

Individual Single Fiber Tensile Test Data for
Nextel 440 at Room Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 1" Gage Length | | | | | | | |
| NX440101 | 88.22 | 1.37 | 0.58 | 83.8* | 126.3 | 18.3* | 0.46* |
| 2 | | | 1.55 | 224.0 | 181.5 | 26.3 | 0.85 |
| 3 | | | 2.21 | 320.0 | 165.6 | 24.0 | 1.33* |
| 5 | | | 1.22 | 177.0 | 188.4 | 27.3 | 0.65 |
| 6 | | | 2.42 | 351.0* | 191.8 | 27.8 | 1.26 |
| 7 | | | 2.10 | 304.0 | 180.8 | 26.2 | 1.16 |
| 8 | | | 1.60 | 232.0 | 182.9 | 26.5 | 0.88 |
| 9 | | | 2.07 | 300.0 | 173.9 | 25.2 | 1.19 |
| Average | 88.22 | 1.37 | 1.79 | 260.0 | 180.8 | 26.2 | 1.00 |
| Std. Dev. | 0 | 0 | 0.39 | 56.8 | 8.8 | 1.3 | 0.24 |
| 2" Gage Length | | | | | | | |
| NX440201 | 88.22 | 1.37 | 1.90 | 276.0* | 223.6 | 32.4* | 0.85 |
| 3 | | | 1.76 | 255.0 | 186.3 | 27.0 | 0.94* |
| 4 | | | 1.44 | 208.0 | 200.8 | 29.1 | 0.71 |
| 6 | | | 0.69 | 100.0* | 176.0 | 25.5 | 0.39* |
| 10 | | | 1.26 | 182.0 | 179.4 | 26.0 | 0.70 |
| Average | 88.22 | 1.37 | 1.48 | 215.0 | 185.6 | 26.9 | 0.75 |
| Std. Dev. | 0 | 0 | 0.26 | 37.0 | 11.0 | 1.6 | 0.08 |
| 4" Gage Length | | | | | | | |
| NX440401 | 88.22 | 1.37 | 1.18 | 171.0* | 167.7 | 24.3 | 0.70* |
| 2 | | | 1.70 | 247.0 | 194.6 | 28.2 | 0.88 |
| 3 | | | 2.30 | 333.0* | 204.9 | 29.7 | 1.12 |
| 4 | | | 1.73 | 251.0 | 189.1 | 27.4 | 0.92 |
| 6 | | | 1.96 | 284.0 | 198.7 | 28.8 | 0.99 |
| 7 | | | 2.14 | 310.0 | 193.2 | 28.0 | 1.11 |
| 8 | | | 2.01 | 291.0 | 177.3 | 25.7 | 1.13* |
| 9 | | | 1.93 | 280.0 | 189.8 | 27.5 | 1.02 |
| 10 | | | 1.88 | 273.0 | 200.1 | 29.0 | 0.94 |
| Average | 88.22 | 1.37 | 1.91 | 277.0 | 190.6 | 27.6 | 1.00 |
| Std. Dev. | 0 | 0 | 0.15 | 22.1 | 11.7 | 1.7 | 0.09 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A10

Individual Single Fiber Tensile Test Data for
Nextel 440 at Elevated Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 500°C, 8" Gage Length | | | | | | | |
| 044081B | 88.22 | 1.37 | 0.77 | 112.1* | 162.9 | 23.6* | 0.47* |
| 2 | | | 1.24 | 179.5 | 190.6 | 27.6 | 0.65 |
| 3 | | | 1.46 | 212.3 | 198.7 | 28.8 | 0.74 |
| 4B | | | 1.57 | 226.9 | 215.9 | 31.3 | 0.73 |
| 5 | | | 1.74 | 252.4* | 260.4 | 37.7* | 0.67 |
| 6 | | | 1.60 | 232.4 | 213.8 | 31.0 | 0.75 |
| 7B | | | 1.50 | 217.0 | 194.8 | 28.2 | 0.77 |
| 8 | | | 1.50 | 216.7 | 182.6 | 26.5 | 0.82 |
| 9 | | | 0.75 | 108.2* | 192.7 | 27.9 | 0.39* |
| 10B | | | 1.63 | 236.8 | 175.5 | 25.4 | 0.93* |
| Average | 88.22 | 1.37 | 1.50 | 217.4 | 195.6 | 28.3 | 0.73 |
| Std. Dev. | 0 | 0 | 0.13 | 18.9 | 13.9 | 2.0 | 0.06 |
| 500°C, 10" Gage Length | | | | | | | |
| 0440101 | 88.22 | 1.37 | 0.99 | 143.1 | 186.3 | 27.0 | 0.53 |
| 2 | | | 1.12 | 162.1 | 172.1 | 24.9 | 0.65 |
| 3C | | | 1.70 | 246.4* | 179.0 | 25.9 | 0.95* |
| 4 | | | 1.22 | 176.2 | 172.4 | 25.0 | 0.71 |
| 5 | | | 1.06 | 153.5 | 189.1 | 27.4 | 0.56 |
| 7 | | | 1.14 | 164.7 | 196.0 | 28.4 | 0.58 |
| 8 | | | 1.64 | 237.3* | 192.6 | 27.9 | 0.85* |
| Average | 88.22 | 1.37 | 1.10 | 159.9 | 183.8 | 26.6 | 0.61 |
| Std. Dev. | 0 | 0 | 0.09 | 12.4 | 9.6 | 1.4 | 0.07 |
| 600°C, 8" Gage Length | | | | | | | |
| 144082 | 88.22 | 1.37 | 0.48 | 70.3 | 209.6 | 30.4 | 0.23* |
| 3 | | | 0.24 | 35.1* | 149.2 | 21.6* | 0.16* |
| 4 | | | 1.48 | 214.7* | 211.6 | 30.7 | 0.70 |
| 5 | | | 1.66 | 240.9* | 190.0 | 27.5 | 0.88* |
| 6 | | | 0.97 | 141.0 | 199.6 | 28.9 | 0.49 |
| 7 | | | 0.78 | 113.4 | 178.9 | 25.9 | 0.44 |
| Average | 88.22 | 1.37 | 0.75 | 108.2 | 198.0 | 28.7 | 0.54 |
| Std. Dev. | 0 | 0 | 0.25 | 35.6 | 13.9 | 2.0 | 0.11 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A10

(Continued)

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Ms) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|----------------------------|---------------------------------|
| 600°C, 10" Gage Length | | | | | | | |
| 1440101 | 88.22 | 1.37 | 1.12 | 162.1 | 192.9 | 28.0 | 0.58 |
| 2 | | | 1.22 | 176.9 | 187.8 | 27.2 | 0.65 |
| 3 | | | 1.43 | 207.6 | 182.5 | 26.5 | 0.78 |
| 4 | | | 0.81 | 117.1* | 171.9 | 24.9 | 0.47* |
| 5 | | | 1.03 | 148.8 | 197.5 | 28.6 | 0.52* |
| 6 | | | 1.65 | 238.9* | 202.2 | 29.3 | 0.81 |
| 7 | | | 1.66 | 240.9* | 201.5 | 29.2 | 0.82 |
| 8 | | | 1.47 | 212.8 | 188.3 | 27.3 | 0.78 |
| Average | 88.22 | 1.37 | 1.25 | 181.7 | 190.6 | 27.6 | 0.75 |
| Std. Dev. | 0 | 0 | 0.19 | 28.0 | 10.2 | 1.5 | 0.10 |
| 700°C, 8" Gage Length | | | | | | | |
| 244081 | 88.22 | 1.37 | 1.44 | 208.9 | 178.8 | 25.9 | 0.81 |
| 2 | | | 1.60 | 231.6 | 195.1 | 28.3 | 0.82 |
| 3 | | | 1.01 | 145.7* | 176.8 | 25.6 | 0.57* |
| 4 | | | 1.54 | 223.8 | 173.9 | 25.2 | 0.89 |
| 5 | | | 1.66 | 240.9 | 198.5 | 28.8* | 0.84 |
| Average | 88.22 | 1.37 | 1.56 | 226.3 | 181.2 | 26.3 | 0.84 |
| Std. Dev. | 0 | 0 | 0.09 | 13.5 | 9.5 | 1.4 | 3.56 |
| 700°C, 10" Gage Length | | | | | | | |
| 2440101 | 88.22 | 1.37 | 0.38 | 54.9* | 151.5 | 22.0* | 0.25* |
| 2 | | | 1.69 | 245.6 | 196.0 | 28.4 | 0.86 |
| 3 | | | 0.93 | 135.3 | 184.9 | 26.8 | 0.51 |
| 4 | | | 1.10 | 158.7 | 182.5 | 26.5 | 0.60 |
| 5 | | | 1.56 | 226.4 | 183.7 | 26.6 | 0.85 |
| 6 | | | 1.81 | 262.8* | 197.1 | 28.6 | 0.92 |
| Average | 88.22 | 1.37 | 1.32 | 191.5 | 188.8 | 27.4 | 0.75 |
| Std. Dev. | 0 | 0 | 0.36 | 52.8 | 7.1 | 1.0 | 0.18 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A10

(Continued)

| Specimen No. | Fiber Area (μm^2) | 10^{-7} in^2 | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|-----------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 800°C, 8" Gage Length | | | | | | | |
| 344081A | 88.22 | 1.37 | 1.62 | 234.2 | 178.3 | 25.8 | 0.91 |
| 2 | | | 0.56 | 81.2* | 194.9 | 28.2 | 0.29* |
| 3 | | | 0.83 | 121.0 | 190.8 | 27.7 | 0.44 |
| 4A | | | 1.80 | 260.2* | 205.2 | 29.7* | 0.88 |
| 5 | | | 1.38 | 200.4 | 170.2 | 24.7 | 0.81 |
| 6 | | | 1.52 | 220.4 | 173.8 | 25.2 | 0.88 |
| 7A | | | 1.44 | 208.2 | 162.9 | 23.6 | 0.88 |
| 8 | | | 0.32 | 46.1* | 113.0 | 16.4* | 0.28* |
| Average | 88.22 | 1.37 | 1.36 | 196.8 | 178.5 | 25.9 | 0.80 |
| Std. Dev. | 0 | 0 | 0.31 | 44.3 | 12.3 | 1.8 | 0.18 |
| 800°C, 10" Gage Length | | | | | | | |
| 3440101 | 88.22 | 1.37 | 1.52 | 219.9 | 226.4 | 32.8* | 0.67 |
| 2 | | | 1.18 | 170.7* | 194.6 | 28.2 | 0.60* |
| 3A | | | 1.68 | 242.8 | 221.8 | 32.2* | 0.75 |
| 4 | | | 1.78 | 258.1* | 203.6 | 29.5 | 0.88* |
| 5 | | | 1.25 | 180.8* | 215.1 | 31.2 | 0.58* |
| 6A | | | 1.48 | 214.1 | 184.7 | 26.8* | 0.80 |
| 7 | | | 1.43 | 206.6 | 205.1 | 29.7 | 0.69 |
| 8 | | | 1.56 | 226.4 | 199.0 | 28.8 | 0.78 |
| 9A | | | 1.64 | 237.6 | 189.5 | 27.5* | 0.86* |
| Average | 88.22 | 1.37 | 1.55 | 224.5 | 203.5 | 29.5 | 0.74 |
| Std. Dev. | 0 | 0 | 0.10 | 13.8 | 7.7 | 1.1 | 0.06 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A11

Individual Single Fiber Tensile Test Data for
NexTEL 480 at Room Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|--|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 1" Gage Length | | | | | | | |
| 048002B | 72.04 | 1.11 | 2.87 | 415.6 | 189.4 | 27.5 | 1.51 |
| 3B | | | 2.57 | 372.2 | 172.5 | 25.0* | 1.49 |
| 4B | | | 2.83 | 410.7 | 163.3 | 23.7* | 1.73* |
| 5B | | | 2.76 | 400.5 | 212.4 | 30.8 | 1.30 |
| 6B | | | 2.62 | 379.5 | 208.3 | 30.2 | 1.24 |
| 7B | | | 2.35 | 340.2* | 205.0 | 29.7 | 1.13 |
| 8B | | | 2.12 | 306.7* | 217.0 | 31.5 | 0.95* |
| 9B | | | 2.99 | 434.0* | 213.2 | 30.9 | 1.38 |
| 10B | | | 2.74 | 397.3 | 225.4 | 32.7* | 1.22 |
| Average | 72.04 | 1.11 | 2.73 | 396.0 | 207.5 | 30.1 | 1.32 |
| Std. Dev. | 0 | 0 | 0.12 | 17.1 | 9.8 | 1.4 | 0.13 |
| 2" Gage Length | | | | | | | |
| 048021B | 72.04 | 1.11 | 1.81 | 262.5 | 231.6 | 33.6 | 0.77 |
| 3B | | | 1.69 | 244.2 | 204.0 | 29.6* | 0.73 |
| 4B | | | 2.77 | 401.8* | 238.8 | 34.6* | 1.15* |
| 5B | | | 1.78 | 258.1 | 194.0 | 28.1* | 0.91 |
| 6B | | | 2.28 | 330.4 | 225.8 | 32.7 | 1.00 |
| 7B | | | 2.59 | 375.5* | 233.8 | 33.9 | 1.09* |
| 8B | | | 2.00 | 290.2 | 216.0 | 31.3 | 0.91 |
| 9B | | | 1.37 | 199.1* | 234.1 | 33.9 | 0.58* |
| 10B | | | 1.95 | 282.2 | 216.9 | 31.4 | 0.89 |
| Average | 72.04 | 1.11 | 1.92 | 277.9 | 226.4 | 32.8 | 0.87 |
| Std. Dev. | 0 | 0 | 0.21 | 30.6 | 8.3 | 1.2 | 0.10 |
| 4" Gage Length | | | | | | | |
| 048041 | 72.04 | 1.11 | 1.93 | 280.0 | 236.0 | 34.2 | 0.82 |
| 2 | | | 1.59 | 229.9* | 213.8 | 31.0* | 0.74 |
| 3 | | | 1.95 | 282.6 | 254.1 | 36.8* | 0.77 |
| 4 | | | 2.35 | 340.2* | 218.9 | 31.7 | 1.07* |
| 5 | | | 2.16 | 313.4 | 231.4 | 33.5 | 0.93 |
| 6 | | | 2.39 | 346.0* | 211.8 | 30.7* | 1.13* |
| 7 | | | 2.09 | 303.6 | 219.2 | 31.8 | 0.95 |
| 8 | | | 2.34 | 339.3* | 249.3 | 36.1* | 0.94 |
| 9 | | | 1.51 | 218.8* | 227.0 | 32.9 | 0.61* |
| 10 | | | 1.36 | 197.8* | 229.0 | 33.2 | 0.60* |
| Average | 72.04 | 1.11 | 2.03 | 294.9 | 226.9 | 32.9 | 0.86 |
| Std. Dev. | 0 | 0 | 0.11 | 16.2 | 6.2 | 0.9 | 0.09 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A12

Individual Single Fiber Tensile Test Data for
Nextel 480 at Elevated Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|--------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 900°C, 8" Gage Length | | | | | | | |
| 948081 | 72.04 | 1.11 | 1.73 | 251.4 | 224.8 | 32.6 | 0.78 |
| 2 | | | 1.61 | 233.5 | 278.6 | 40.4* | 0.57* |
| 3 | | | 1.90 | 275.9* | 262.6 | 38.1 | 0.72 |
| 4 | | | 1.51 | 218.8* | 217.2 | 31.5 | 0.68 |
| 5 | | | 1.85 | 268.3 | 226.4 | 32.8 | 0.81* |
| Average | 72.04 | 1.11 | 1.73 | 251.1 | 232.8 | 33.7 | 0.73 |
| Std. Dev. | 0 | 0 | 0.12 | 17.4 | 20.3 | 2.9 | 0.05 |
| 1000°C, 8" Gage Length | | | | | | | |
| 048081A | 72.04 | 1.11 | 0.75 | 108.9* | 188.4 | 27.3* | 0.40* |
| 2A | | | 1.86 | 269.9 | 302.2 | 43.8* | 0.62 |
| 3A | | | 1.91 | 276.4 | 291.2 | 42.2 | 0.65 |
| 4A | | | 1.56 | 226.6 | 213.6 | 31.0 | 0.73 |
| 5A | | | 1.62 | 234.4 | 216.5 | 31.4 | 0.75 |
| Average | 72.04 | 1.11 | 1.74 | 251.8 | 240.4 | 34.8 | 0.69 |
| Std. Dev. | 0 | 0 | 0.17 | 25.0 | 44.0 | 6.4 | 0.05 |
| 1000°C, 10" Gage Length | | | | | | | |
| 0480101A | 72.04 | 1.11 | 1.21 | 174.8 | 236.9 | 34.3 | 0.50 |
| 2A | | | 0.86 | 124.1* | 267.0 | 38.7* | 0.32* |
| 3A | | | 1.52 | 220.6* | 253.4 | 36.7 | 0.60 |
| 4A | | | 1.16 | 168.5 | 232.8 | 33.7 | 0.50 |
| 5A | | | 1.26 | 182.6 | 202.2 | 29.3* | 0.62* |
| 6A | | | 0.84 | 121.4* | 221.3 | 32.1 | 0.38 |
| Average | 72.04 | 1.11 | 1.21 | 175.3 | 236.1 | 34.2 | 0.50 |
| Std. Dev. | 0 | 0 | 0.05 | 7.0 | 13.3 | 1.9 | .09 |
| 1100°C, 8" Gage Length | | | | | | | |
| 148081 | 72.04 | 1.11 | 0.22 | 32.4* | 169.5 | 24.6 | 0.13* |
| 2 | | | 0.36 | 52.7 | 178.4 | 25.9 | 0.19 |
| 3 | | | 0.51 | 74.6 | 168.4 | 24.4 | 0.31 |
| 4 | | | 0.46 | 67.0 | 190.9 | 27.7 | 0.22 |
| 5 | | | 0.75 | 109.4* | 210.6 | 30.5* | 0.38* |
| Average | 72.04 | 1.11 | 0.45 | 64.7 | 176.8 | 25.6 | 0.24 |
| Std. Dev. | 0 | 0 | 0.08 | 11.1 | 10.4 | 1.5 | 0.06 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A12

(Continued)

| Specimen No. | Fiber Area (μm^2) | 10^{-7} in 2 | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|-------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 1200°C, 8" Gage Length | | | | | | | |
| 248081A | 72.04 | 1.11 | 0.20 | 28.6* | 220.9 | 32.0 | 0.08* |
| 2A | | | 0.56 | 81.5 | 220.9 | 32.0 | 0.25 |
| 3A | | | 0.55 | 80.4 | 220.9 | 32.0 | 0.25 |
| 4A | | | 0.34 | 48.7 | 175.1 | 25.4* | 0.18 |
| 5A | | | 0.27 | 39.1 | 210.8 | 30.6 | 0.13 |
| 6A | | | 0.54 | 78.1 | 208.0 | 30.2 | 0.29* |
| Average | 72.04 | 1.11 | 0.45 | 65.5 | 216.3 | 31.4 | 0.20 |
| Std. Dev. | 0 | 0 | 0.14 | 20.1 | 6.4 | 0.9 | 0.06 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A13

Individual Single Fiber Tensile Test Data for
Uncoated Nextel 480 at Room Temperature

| Specimen No. | Fiber Area (μm^2) | (10^{-7} in^2) | Tensile Strength (GPa) | (ksi) | Tensile Modulus (GPa) | (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|---------------------------|------------------------------|--------|-----------------------------|-------|---------------------------------|
| 1" Gage Length | | | | | | | |
| 048011A | 72.04 | 1.11 | 2.22 | 322.2 | 243.2 | 35.3 | 0.92 |
| 2A | | | 2.29 | 331.9 | 224.0 | 32.5 | 1.01 |
| 3A | | | 2.00 | 290.0* | 227.0 | 32.9 | 0.88* |
| 4A | | | 3.04 | 440.0* | 239.0 | 34.6 | 1.26* |
| 5A | | | 2.91 | 422.2 | 221.7 | 32.1* | 1.32* |
| 6A | | | 2.78 | 403.4 | 232.3 | 33.7 | 1.20 |
| 7 | | | 2.09 | 303.4* | 234.2 | 33.9 | 0.87* |
| 8 | | | 3.14 | 455.6* | 259.1 | 37.6* | 1.21 |
| 9 | | | 2.51 | 364.5 | 240.7 | 34.9 | 1.07 |
| 10 | | | 2.38 | 344.5 | 228.9 | 33.2 | 1.04 |
| Average | 72.04 | 1.11 | 2.52 | 364.8 | 233.7 | 33.9 | 1.07 |
| Std. Dev. | 0 | 0 | 0.28 | 40.2 | 6.9 | 1.0 | 0.11 |
| 2" Gage Length | | | | | | | |
| 048021 | 72.04 | 1.11 | 2.39 | 346.7 | 299.9 | 43.5* | 0.80 |
| 2 | | | 2.88 | 416.7 | 302.8 | 43.9* | 0.96 |
| 3 | | | 3.28 | 475.6* | 307.7 | 44.6* | 1.06 |
| 4 | | | 2.63 | 381.1 | 277.1 | 40.2 | 0.95 |
| 5 | | | 2.15 | 311.1 | 231.3 | 33.5 | 0.92 |
| 6 | | | 2.63 | 381.1 | 201.9 | 29.3* | 1.35* |
| 7 | | | 1.72 | 248.9* | 227.6 | 33.0 | 0.75* |
| 8 | | | 2.15 | 311.1 | 222.8 | 32.3 | 0.96 |
| 9 | | | 2.42 | 351.1 | 249.8 | 36.2 | 0.98 |
| 10 | | | 2.09 | 303.4 | 259.0 | 37.5 | 0.81 |
| Average | 72.04 | 1.11 | 2.42 | 350.3 | 244.6 | 35.4 | 0.93 |
| Std. Dev. | 0 | 0 | 0.28 | 40.7 | 21.1 | 3.1 | 0.09 |
| 4" Gage Length | | | | | | | |
| 048042 | 72.04 | 1.11 | 1.52 | 221.0 | 271.0 | 39.3 | 0.57 |
| 4 | | | 1.29 | 187.5* | 283.1 | 41.0 | 0.46* |
| 6 | | | 1.77 | 256.7 | 336.7 | 48.8* | 0.53 |
| 7 | | | 2.39 | 346.9* | 310.3 | 45.0 | 0.77 |
| 9 | | | 2.43 | 352.7* | 262.9 | 38.1 | 0.92* |
| 10 | | | 1.86 | 270.1 | 252.7 | 36.6* | 0.73 |
| Average | 72.04 | 1.11 | 1.72 | 249.3 | 281.8 | 40.8 | 0.62 |
| Std. Dev. | 0 | 0 | 0.18 | 25.4 | 20.7 | 3.0 | 0.12 |

* Numbers not used in calculating Average and Standard Deviation

Table A14

Individual Single Fiber Tensile Test Data for
Boron-Nitride Coated Nicalon NLM-102 at Room Temperature

| Specimen No. | Fiber Area (μm^2) | (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|---------------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 1" Gage Length | | | | | | | |
| NLM102 | 174.37 | 2.70 | 1.12 | 162.0* | 133.9 | 19.4 | 0.84* |
| 3 | | | 2.01 | 291.0 | 120.8 | 17.5 | 1.66 |
| 4 | | | 1.64 | 237.0 | 97.3 | 14.1* | 1.68 |
| 5 | | | 1.89 | 274.0 | 107.0 | 15.5 | 1.76 |
| 6 | | | 2.49 | 361.0 | 211.8 | 30.7* | 1.18 |
| 7 | | | 1.89 | 274.0 | 122.1 | 17.7 | 1.55 |
| 8 | | | 2.82 | 409.0* | 140.1 | 20.3 | 2.02* |
| 10 | | | 1.95 | 282.0 | 147.7 | 21.4 | 1.32 |
| Average | 174.37 | 2.70 | 1.98 | 287.0 | 128.3 | 18.6 | 1.52 |
| Std. Dev. | 0 | 0 | 0.28 | 40.9 | 14.8 | 2.1 | 0.23 |
| 2" Gage Length | | | | | | | |
| NLM201 | 174.37 | 2.70 | 2.01 | 291.0* | 142.1 | 20.6* | 1.41 |
| 3 | | | 2.48 | 359.0 | 146.3 | 21.2* | 1.69* |
| 4 | | | 3.57 | 518.0 | 244.3 | 35.4 | 1.46 |
| 5 | | | 1.89 | 274.0* | 196.0 | 28.4 | 0.97* |
| 6 | | | 2.66 | 386.0 | 174.6 | 25.3 | 1.53 |
| 7 | | | 3.34 | 484.0 | 305.7 | 44.3* | 1.09* |
| 8 | | | 2.28 | 331.0 | 206.3 | 29.9 | 1.11 |
| 9 | | | 4.61 | 668.0* | 308.4 | 44.7* | 1.50 |
| 10 | | | 3.21 | 465.0 | 226.3 | 32.8 | 1.42 |
| Average | 174.37 | 2.70 | 2.93 | 424.0 | 209.8 | 30.4 | 1.41 |
| Std. Dev. | 0 | 0 | 0.52 | 75.4 | 26.9 | 3.9 | 0.15 |
| 4" Gage Length | | | | | | | |
| NLM401 | 174.37 | 2.70 | 2.55 | 370.0 | 255.6 | 32.7 | 1.13 |
| 2 | | | 2.86 | 415.0* | 289.1 | 41.9* | 0.99* |
| 3 | | | 2.82 | 409.0* | 196.0 | 28.4 | 1.44* |
| 4 | | | 2.15 | 312.0 | 167.7 | 24.3 | 1.28 |
| 5 | | | 1.95 | 282.0 | 142.8 | 20.7* | 1.36 |
| 6 | | | 1.84 | 266.0 | 184.9 | 26.8 | 0.99* |
| 7 | | | 1.66 | 241.0* | 172.5 | 25.0 | 0.97* |
| 9 | | | 2.24 | 324.0 | 155.9 | 22.6 | 1.43* |
| Average | 174.37 | 2.70 | 2.15 | 311.0 | 183.5 | 26.6 | 1.26 |
| Std. Dev. | 0 | 0 | 0.28 | 40.4 | 24.8 | 3.6 | 0.12 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A15

Individual Single Fiber Tensile Test Data for
Boron-Nitride Coated Nicalon NLM-102 at Elevated Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 500°C, 8" Gage Length | | | | | | | |
| ONLM182 | 174.37 | 2.70 | 0.91 | 132.3 | 85.9 | 12.5 | 1.06 |
| 3 | | | 0.65 | 94.0* | 54.6 | 7.9* | 1.19* |
| 4 | | | 0.90 | 130.2 | 80.7 | 11.7 | 1.11 |
| 5 | | | 0.63 | 91.5 | 87.1 | 12.6 | 0.73* |
| 7 | | | 0.89 | 128.9 | 98.2 | 14.2* | 0.91 |
| Average | 174.37 | 2.70 | 0.90 | 130.5 | 84.9 | 12.3 | 1.03 |
| Std. Dev. | 0 | 0 | 0.01 | 1.7 | 3.4 | 0.5 | 0.10 |
| 500°C, 10" Gage Length | | | | | | | |
| ONLM1101 | 174.37 | 2.70 | 2.05 | 297.4 | 205.2 | 29.7 | 1.00 |
| 2 | | | 1.96 | 284.1 | 186.6 | 27.1 | 1.05 |
| 3 | | | 1.59 | 230.8 | 193.1 | 28.0 | 0.82 |
| 4 | | | 1.16 | 168.5* | 183.1 | 26.5 | 0.63* |
| 9 | | | 1.81 | 261.6 | 148.6 | 21.5* | 1.21* |
| 10 | | | 1.92 | 278.7 | 211.3 | 30.6* | 0.91 |
| Average | 174.37 | 2.70 | 1.87 | 270.5 | 192.0 | 27.8 | 0.95 |
| Std. Dev. | 0 | 0 | 0.18 | 25.6 | 9.7 | 1.4 | 0.10 |
| 600°C, 8" Gage Length | | | | | | | |
| 1NLM181 | 174.37 | 2.70 | 0.95 | 137.3* | 151.5 | 22.0 | 0.63* |
| 2 | | | 1.13 | 163.9 | 153.3 | 22.2 | 0.74 |
| 3 | | | 2.93 | 424.2* | 230.7 | 33.4* | 1.27* |
| 4 | | | 1.56 | 225.4 | 179.1 | 26.0 | 0.87 |
| 5 | | | 1.38 | 199.6 | 183.7 | 26.6 | 0.75 |
| 6 | | | 2.22 | 321.1 | 179.1 | 26.0 | 1.24* |
| 7 | | | 1.14 | 165.5 | 140.6 | 20.4* | 0.81 |
| 8 | | | 1.29 | 186.3 | 136.2 | 19.7* | 0.94 |
| 9 | | | 1.43 | 208.0 | 158.4 | 23.0 | 0.91 |
| 10 | | | 2.18 | 316.1 | 190.7 | 27.6 | 1.14 |
| Average | 174.37 | 2.70 | 1.54 | 223.2 | 170.8 | 24.8 | 0.88 |
| Std. Dev. | 0 | 0 | 0.43 | 62.3 | 16.0 | 2.3 | 0.14 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A15

(Continued)

| Specimen No. | Fiber Area (μm^2) | (10^{-7} in^2) | Tensile Strength (GPa) | (ksi) | Tensile Modulus (GPa) | (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---------------------------|---------------------------|--------|--------------------------|-------|------------------------------|
| 600°C, 10" Gage Length | | | | | | | |
| 1NLM1101 | 174.37 | 2.70 | 1.61 | 232.9 | 172.8 | 25.0 | 0.93 |
| 2 | | | 2.05 | 297.4* | 190.0 | 27.5* | 1.08 |
| 3 | | | 1.55 | 224.6 | 140.9 | 20.4* | 1.10 |
| 4 | | | 1.46 | 212.1* | 168.2 | 24.4 | 0.87* |
| 5 | | | 1.58 | 228.8 | 158.6 | 23.0 | 0.99 |
| 6 | | | 1.84 | 266.2 | 144.6 | 21.0* | 1.27* |
| 7 | | | 1.73 | 251.2 | 162.8 | 23.6 | 1.06 |
| Average | 174.37 | 2.70 | 1.66 | 240.7 | 165.6 | 24.0 | 1.03 |
| Std. Dev. | 0 | 0 | 0.12 | 17.5 | 6.4 | 0.9 | 0.07 |
| 700°C, 8" Gage Length | | | | | | | |
| 2NLM181 | 174.37 | 2.70 | 1.52 | 220.9* | 157.3 | 22.8 | 0.97* |
| 2 | | | 1.88 | 272.4 | 196.6 | 28.5 | 0.96* |
| 3 | | | 2.13 | 308.2 | 170.2 | 24.7 | 1.25* |
| 4 | | | 2.64 | 382.7* | 215.6 | 31.2* | 1.22* |
| 5 | | | 2.38 | 345.2 | 204.9 | 29.7 | 1.16 |
| 6 | | | 1.41 | 204.6* | 149.6 | 21.7* | 0.94* |
| 7 | | | 2.41 | 349.4 | 197.8 | 28.7 | 1.22* |
| 8 | | | 1.45 | 210.0* | 136.3 | 19.8* | 1.06 |
| 9 | | | 2.00 | 290.3 | 186.4 | 27.0 | 1.08 |
| Average | 174.37 | 2.70 | 2.16 | 313.1 | 185.5 | 26.9 | 1.10 |
| Std. Dev. | 0 | 0 | 0.23 | 33.7 | 18.3 | 2.7 | 0.05 |
| 700°C, 10" Gage Length | | | | | | | |
| 2NLM1106 | 174.37 | 2.70 | 1.81 | 262.0 | 170.6 | 24.7* | 1.06 |
| 7 | | | 1.66 | 240.0 | 191.4 | 27.7 | 0.86 |
| 8 | | | 2.35 | 341.1* | 208.2 | 30.2 | 1.13* |
| 9 | | | 1.11 | 161.4* | 178.2 | 25.8 | 0.63* |
| 10 | | | 1.43 | 207.5 | 210.6 | 30.5* | 0.68 |
| Average | 174.37 | 2.70 | 1.63 | 236.5 | 192.6 | 27.9 | 0.87 |
| Std. Dev. | 0 | 0 | 0.19 | 27.4 | 15.1 | 2.2 | 0.19 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A15

(Continued)

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 800°C, 8" Gage Length | | | | | | | |
| 3NLM181 | 174.37 | 2.70 | 1.66 | 241.2 | 115.8 | 16.8 | 1.44* |
| 2 | | | 1.12 | 162.2 | 167.4 | 24.3 | 0.67* |
| 3 | | | 1.16 | 168.5 | 112.1 | 16.2* | 1.04 |
| 4 | | | 1.00 | 145.6* | 119.0 | 17.3 | 0.84 |
| 5 | | | 1.02 | 148.5* | 122.3 | 17.7 | 0.84 |
| 6 | | | 1.87 | 270.4* | 192.6 | 27.9* | 0.97 |
| 7 | | | 1.94 | 280.8* | 202.6 | 29.4* | 0.96 |
| 8 | | | <u>1.66</u> | <u>241.2</u> | <u>166.4</u> | <u>24.1</u> | <u>1.00</u> |
| Average | 174.37 | 2.70 | 1.40 | 203.3 | 138.2 | 20.0 | 0.94 |
| Std. Dev. | 0 | 0 | 0.30 | 43.9 | 26.3 | 3.8 | 0.08 |
| 800°C, 10" Gage Length | | | | | | | |
| 3NLM1102 | 174.37 | 2.70 | 2.32 | 336.9 | 194.5 | 28.2 | 1.19* |
| 4 | | | 0.77 | 111.9* | 129.7 | 18.8* | 0.59* |
| 5 | | | 1.92 | 278.3 | 224.5 | 32.5 | 0.86 |
| 6 | | | 2.32 | 336.1 | 225.1 | 32.6 | 1.03 |
| 7 | | | 1.23 | 178.9 | 144.3 | 20.9* | 0.86 |
| 8 | | | <u>2.41</u> | <u>349.4</u> | <u>219.1</u> | <u>31.8</u> | <u>1.10</u> |
| Average | 174.37 | 2.70 | 2.04 | 295.9 | 215.8 | 31.3 | 0.96 |
| Std. Dev. | 0 | 0 | 0.49 | 71.0 | 14.5 | 2.1 | 0.12 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A16

Individual Single Fiber Tensile Test Data for
Boron-Nitride Coated Nextel 312 at Room Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 1" Gage Length | | | | | | | |
| 0312101 | 88.22 | 1.37 | 1.61 | 233.0* | 161.5 | 23.4 | 1.00 |
| 2 | | | 1.46 | 212.0 | 153.2 | 22.2 | 0.96 |
| 3 | | | 1.15 | 166.0 | 176.0 | 25.5 | 0.65 |
| 4 | | | 0.92 | 134.0* | 154.6 | 22.4 | 0.60* |
| 6 | | | 1.30 | 189.0 | 157.3 | 22.8 | 0.83 |
| 7 | | | 1.55 | 224.0 | 160.1 | 23.2 | 0.97* |
| 8 | | | 0.91 | 132.0* | 146.3 | 21.2 | 0.62 |
| 9 | | | 1.32 | 191.0 | 188.4 | 27.3 | 0.70 |
| Average | 88.22 | 1.37 | 1.35 | 196.0 | 162.2 | 23.5 | 0.79 |
| Std. Dev. | 0 | 0 | 0.15 | 22.4 | 13.6 | 2.0 | 0.16 |
| 2" Gage Length | | | | | | | |
| 0312201 | 88.22 | 1.37 | 1.44 | 208.0* | 182.2 | 26.4 | 0.79* |
| 4 | | | 0.88 | 127.0 | 160.1 | 23.2 | 0.55 |
| 5 | | | 0.75 | 109.0* | 159.4 | 23.1 | 0.47* |
| 7 | | | 1.26 | 182.0 | 187.0 | 27.1 | 0.67 |
| 8 | | | 1.35 | 196.0 | 180.1 | 26.1 | 0.75 |
| 10 | | | 1.07 | 155.0 | 162.8 | 23.6 | 0.66 |
| Average | 88.22 | 1.37 | 1.14 | 165.0 | 171.9 | 24.9 | 0.66 |
| Std. Dev. | 0 | 0 | 0.21 | 30.5 | 12.5 | 1.8 | 0.08 |
| 4" Gage Length | | | | | | | |
| 0312401 | 88.22 | 1.37 | 0.79 | 115.0* | 161.5 | 23.4 | 0.49* |
| 2 | | | 1.58 | 229.0* | 164.2 | 23.8 | 0.97* |
| 3 | | | 1.18 | 171.0 | 180.1 | 26.1 | 0.66 |
| 4 | | | 1.13 | 164.0 | 160.1 | 23.2 | 0.71 |
| 5 | | | 1.15 | 166.0 | 171.1 | 24.8 | 0.67 |
| 6 | | | 1.41 | 204.0 | 171.8 | 24.9 | 0.82 |
| 7 | | | 1.12 | 163.0 | 165.6 | 24.0 | 0.68 |
| 8 | | | 1.51 | 219.0* | 190.4 | 27.6 | 0.79 |
| 10 | | | 1.00 | 145.0 | 168.4 | 24.4 | 0.60 |
| Average | 88.22 | 1.37 | 1.17 | 169.0 | 170.4 | 24.7 | 0.70 |
| Std. Dev. | 0 | 0 | 0.13 | 19.4 | 9.7 | 1.4 | 0.08 |

* Numbers not used in calculating the Average and Standard Deviation.

Table A17

Individual Single Fiber Tensile Test Data for
Boron-Nitride Coated Nextel 312 at Elevated Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 500°C, 8" Gage Length | | | | | | | |
| 0BN3181 | 88.22 | 1.37 | 1.18 | 171.5* | 164.6 | 23.9 | 0.72* |
| 2 | | | 1.15 | 167.0 | 167.5 | 24.3 | 0.69 |
| 3 | | | 0.98 | 142.7 | 164.1 | 23.8 | 0.60 |
| 4 | | | 1.15 | 166.5 | 171.8 | 24.9* | 0.67 |
| 5 | | | 0.97 | 140.5* | 161.6 | 23.4* | 0.60 |
| 6 | | | 1.01 | 145.7 | 165.8 | 24.0 | 0.61 |
| Average | 88.22 | 1.37 | 1.07 | 155.5 | 165.5 | 24.0 | 0.63 |
| Std. Dev. | 0 | 0 | 0.09 | 13.1 | 1.5 | 0.2 | 0.04 |
| 500°C, 10" Gage Length | | | | | | | |
| 0BN31102 | 88.22 | 1.37 | 0.51 | 73.4* | 166.0 | 24.1 | 0.30* |
| 3 | | | 1.22 | 176.9* | 180.8 | 26.2* | 0.67 |
| 4 | | | 0.76 | 109.8 | 168.4 | 24.4 | 0.45 |
| 5 | | | 1.06 | 154.0 | 156.3 | 22.7 | 0.68 |
| 8 | | | 1.06 | 153.5 | 160.5 | 23.3 | 0.66 |
| 9 | | | 1.02 | 148.3 | 155.0 | 22.5 | 0.66 |
| 10 | | | 0.97 | 140.5 | 155.1 | 22.5 | 0.63 |
| Average | 88.22 | 1.37 | 0.97 | 141.2 | 160.2 | 23.2 | 0.63 |
| Std. Dev. | 0 | 0 | 0.13 | 18.4 | 5.8 | 0.8 | 0.09 |
| 600°C, 8" Gage Length | | | | | | | |
| 1BN3181 | 88.22 | 1.37 | 1.08 | 156.1 | 172.4 | 25.0 | 0.63 |
| 2 | | | 0.96 | 139.7* | 160.7 | 23.3* | 0.60 |
| 3 | | | 1.06 | 153.5 | 188.3 | 27.3* | 0.56* |
| 4 | | | 1.04 | 151.2 | 175.7 | 25.5 | 0.59 |
| 5 | | | 1.13 | 163.9 | 167.5 | 24.3 | 0.68 |
| 6 | | | 1.07 | 155.1 | 169.5 | 24.6 | 0.63 |
| 7 | | | 1.25 | 181.9* | 177.7 | 25.8 | 0.71* |
| Average | 88.22 | 1.37 | 1.08 | 156.0 | 172.6 | 25.0 | 0.63 |
| Std. Dev. | 0 | 0 | 0.03 | 4.8 | 4.2 | 0.6 | 0.04 |

* Numbers not used in calculating the Average and Standard Deviation.

Table A17

(Continued)

| Specimen No. | Fiber Area | | Tensile Strength | | Tensile Modulus | | Ultimate Strain |
|-------------------------------|---------------------|---------------------------|------------------|--------|-----------------|-------|-----------------|
| | (μm^2) | (10^{-7} in^2) | (GPa) | (ksi) | (GPa) | (Msi) | (percent) |
| 600°C, 10" Gage Length | | | | | | | |
| 1BN31101 | 88.22 | 1.37 | 0.89 | 128.8 | 164.6 | 23.9 | 0.54 |
| 2 | | | 0.91 | 132.2 | 165.8 | 24.0 | 0.55 |
| 3 | | | 0.92 | 132.7 | 147.7 | 21.4* | 0.62 |
| 4 | | | 0.52 | 75.5 | 170.7 | 24.7 | 0.30 |
| 5 | | | 0.98 | 142.3 | 173.8 | 25.2* | 0.56 |
| 6 | | | 1.03 | 149.6 | 163.9 | 23.8 | 0.63 |
| 7 | | | 0.27 | 39.0* | 168.3 | 24.4 | 0.16* |
| Average | 88.22 | 1.37 | 0.88 | 126.8 | 166.7 | 24.2 | 0.53 |
| Std. Dev. | 0 | 0 | 0.18 | 26.3 | 2.8 | 0.4 | 0.12 |
| 700°C, 8" Gage Length | | | | | | | |
| 2BN3181 | 88.22 | 1.37 | 1.25 | 181.9 | 170.2 | 24.7 | 0.74 |
| 3 | | | 1.45 | 210.8* | 160.5 | 23.3 | 0.91* |
| 4 | | | 1.13 | 163.9 | 190.5 | 27.6* | 0.59 |
| 5 | | | 0.50 | 72.9* | 146.2 | 21.2* | 0.34* |
| 6 | | | 1.10 | 158.7 | 159.3 | 23.1 | 0.69 |
| 7 | | | 0.61 | 88.7* | 163.3 | 23.7 | 0.37* |
| 8 | | | 1.36 | 197.7 | 186.6 | 27.0* | 0.73 |
| 9 | | | 1.01 | 145.7 | 153.2 | 22.2 | 0.66 |
| 10 | | | 1.15 | 167.3 | 190.4 | 27.6* | 0.61 |
| Average | 88.22 | 1.37 | 1.17 | 169.2 | 161.3 | 23.4 | 0.67 |
| Std. Dev. | 0 | 0 | 0.13 | 18.3 | 6.2 | 0.9 | 0.06 |
| 700°C, 10" Gage Length | | | | | | | |
| 2BN31104 | 88.22 | 1.37 | 1.05 | 152.2 | 181.1 | 26.2* | 0.58 |
| 5 | | | 1.18 | 171.7 | 161.2 | 23.4 | 0.74 |
| 6 | | | 1.02 | 148.3 | 146.2 | 21.2 | 0.70 |
| 7 | | | 0.93 | 135.3 | 177.8 | 25.8* | 0.52* |
| 8 | | | 1.34 | 193.6* | 162.9 | 23.6 | 0.82* |
| 9 | | | 1.01 | 145.7 | 143.7 | 20.8 | 0.70 |
| 10 | | | 0.83 | 119.7* | 142.4 | 20.6* | 0.58 |
| Average | 88.22 | 1.37 | 1.04 | 150.6 | 153.5 | 22.2 | 0.66 |
| Std. Dev. | 0 | 0 | 0.09 | 13.3 | 10.0 | 1.4 | 0.07 |

* Numbers not used in calculating the Average and Standard Deviation.

Table A17

(Continued)

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 800°C, 8" Gage Length | | | | | | | |
| 3BN3181 | 88.22 | 1.37 | 1.13 | 164.4 | 181.5 | 26.3 | 0.63 |
| 2 | | | 0.97 | 140.5 | 172.4 | 25.0 | 0.56 |
| 3 | | | 1.22 | 176.4 | 173.9 | 25.2 | 0.70 |
| 4 | | | 1.08 | 156.1 | 152.5 | 22.1 | 0.71 |
| 5 | | | 1.01 | 145.7 | 189.3 | 27.4* | 0.53* |
| 6 | | | 0.66 | 96.3* | 131.2 | 19.0* | 0.51* |
| 7 | | | 1.25 | 181.1 | 163.9 | 23.8 | 0.76* |
| 8 | | | 1.03 | 148.8 | 159.5 | 23.1 | 0.64 |
| 9 | | | 1.28 | 185.3* | 182.6 | 26.5 | 0.70 |
| Average | 88.22 | 1.37 | 1.10 | 159.0 | 169.5 | 24.6 | 0.66 |
| Std. Dev. | 0 | 0 | 0.11 | 15.6 | 11.3 | 1.6 | 0.06 |
| 800°C, 10" Gage Length | | | | | | | |
| 3BN31101 | 88.22 | 1.37 | 0.94 | 136.1 | 147.9 | 21.4 | 0.63 |
| 2 | | | 1.10 | 159.5* | 180.4 | 26.2* | 0.61* |
| 3 | | | 0.99 | 143.1 | 151.9 | 22.0 | 0.65 |
| 4 | | | 1.05 | 152.2 | 152.2 | 22.1 | 0.69* |
| 5 | | | 0.92 | 134.0 | 150.4 | 21.8 | 0.61 |
| 6 | | | 0.87 | 125.4* | 131.1 | 19.0* | 0.66 |
| Average | 88.22 | 1.37 | 0.98 | 141.3 | 150.6 | 21.8 | 0.64 |
| Std. Dev. | 0 | 0 | 0.06 | 8.2 | 2.0 | 0.3 | 0.02 |

* Numbers not used in calculating the Average and Standard Deviation.

Table A18

Individual Single Fiber Tensile Test Data for
Boron-Nitride Coated Nextel 440 at Room Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 1" Gage Length | | | | | | | |
| BN440102 | 115.10 | 1.78 | 1.09 | 158.0 | 137.3 | 19.9 | 0.79 |
| 4 | | | 0.97 | 140.0 | 136.6 | 19.8 | 0.70 |
| 5 | | | 0.49 | 71.2* | 124.9 | 18.1 | 0.39 |
| 6 | | | 1.46 | 212.0 | 139.4 | 20.2 | 1.05* |
| 7 | | | 1.66 | 240.0* | 603.8 | 87.5* | 0.27* |
| Average | 115.10 | 1.78 | 1.17 | 170.0 | 134.6 | 19.5 | 0.63 |
| Std. Dev. | 0 | 0 | 0.26 | 37.5 | 6.5 | 0.9 | 0.21 |
| 2" Gage Length | | | | | | | |
| BN440201 | 115.10 | 1.78 | 1.73 | 251.0* | 146.3 | 21.2 | 1.18* |
| 2 | | | 1.59 | 230.0 | 139.4 | 20.2 | 1.14 |
| 4 | | | 1.34 | 194.0 | 143.5 | 20.8 | 0.94 |
| 9 | | | 0.81 | 117.0 | 190.4 | 27.6* | 0.43* |
| 10 | | | 0.65 | 94.3* | 121.4 | 17.6* | 0.54 |
| Average | 115.10 | 1.78 | 1.24 | 180.0 | 142.8 | 20.7 | 0.87 |
| Std. Dev. | 0 | 0 | 0.40 | 57.7 | 3.5 | 0.5 | 0.31 |
| 4" Gage Length | | | | | | | |
| BN440401 | 115.10 | 1.78 | 0.83 | 120.0* | 149.0 | 21.6 | 0.55* |
| 2 | | | 0.81 | 117.0* | 147.7 | 21.4 | 0.54* |
| 3 | | | 0.97 | 140.0 | 159.4 | 23.1 | 0.61 |
| 4 | | | 1.17 | 170.0 | 147.0 | 21.3 | 0.80 |
| 5 | | | 1.26 | 182.0 | 153.9 | 22.3 | 0.81 |
| 6 | | | 1.14 | 165.0 | 135.9 | 19.7 | 0.84 |
| 7 | | | 0.81 | 117.0* | 123.5 | 17.9 | 0.65 |
| 9 | | | 1.40 | 203.0* | 151.1 | 21.9 | 0.92* |
| 10 | | | 1.50 | 217.0* | 150.4 | 21.8 | 1.00* |
| Average | 115.10 | 1.78 | 1.13 | 164.0 | 146.4 | 21.2 | 0.74 |
| Std. Dev. | 0 | 0 | 0.12 | 17.7 | 10.6 | 1.5 | 0.10 |

* Numbers not used in calculating Average and Standard Deviation.

Table A19

Individual Single Fiber Tensile Test Data for
Boron-Nitride Coated Nextel 440 at Elevated Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 500°C, 8" Gage Length | | | | | | | |
| 0BN4481A | 115.10 | 1.78 | 0.50 | 72.0* | 137.0 | 19.9 | 0.36* |
| 2 | | | 0.67 | 96.7 | 169.5 | 24.6* | 0.39 |
| 3 | | | 0.69 | 99.7 | 141.1 | 20.5 | 0.49 |
| 4A | | | 0.61 | 88.7 | 144.1 | 20.9 | 0.43 |
| 5 | | | 0.57 | 82.6 | 151.9 | 22.0 | 0.37 |
| 6 | | | 0.84 | 121.1* | 146.8 | 21.3 | 0.57* |
| 7A | | | 0.68 | 97.9 | 116.3 | 16.9* | 0.58* |
| Average | 115.10 | 1.78 | 0.64 | 93.1 | 144.2 | 20.9 | 0.42 |
| Std. Dev. | 0 | 0 | 0.05 | 7.2 | 5.7 | 0.8 | 0.05 |
| 500°C, 10" Gage Length | | | | | | | |
| 0BN44101 | 115.10 | 1.78 | 0.83 | 120.3 | 146.8 | 21.3 | 0.56 |
| 2 | | | 0.88 | 127.8 | 138.9 | 20.1 | 0.63* |
| 3A | | | 0.77 | 112.3 | 151.9 | 22.0 | 0.51 |
| 4 | | | 0.59 | 85.8* | 128.6 | 18.6 | 0.46* |
| 5 | | | 1.09 | 158.5* | 190.2 | 27.6* | 0.57 |
| Average | 115.10 | 1.78 | 0.83 | 120.1 | 141.6 | 20.5 | 0.55 |
| Std. Dev. | 0 | 0 | 0.05 | 7.8 | 10.1 | 1.5 | 0.03 |
| 600°C, 8" Gage Length | | | | | | | |
| 1BN4481 | 115.10 | 1.78 | 0.85 | 122.8* | 171.7 | 24.9* | 0.49 |
| 2 | | | 0.89 | 129.6* | 168.4 | 24.4 | 0.53* |
| 3 | | | 0.66 | 95.7 | 167.7 | 24.3 | 0.39 |
| 4 | | | 0.83 | 120.7 | 153.1 | 22.2 | 0.54* |
| 5 | | | 0.49 | 70.8 | 156.3 | 22.7 | 0.31* |
| 6 | | | 0.35 | 50.7* | 139.8 | 20.3* | 0.25* |
| 7 | | | 0.44 | 63.8* | 125.8 | 18.2* | 0.35 |
| 8 | | | 0.70 | 101.7 | 160.4 | 23.3 | 0.44 |
| 9 | | | 0.72 | 103.7 | 148.7 | 21.6 | 0.48 |
| 10 | | | 0.65 | 93.7 | 159.2 | 23.1 | 0.41 |
| Average | 115.10 | 1.78 | 0.67 | 97.7 | 159.1 | 23.1 | 0.43 |
| Std. Dev. | 0 | 0 | 0.11 | 16.3 | 7.2 | 1.0 | 0.05 |
| 600°C, 10" Gage Length | | | | | | | |
| 1BN44101 | 115.10 | 1.78 | 0.82 | 119.1 | 182.6 | 26.5* | 0.45 |
| 2 | | | 1.02 | 147.6* | 166.9 | 24.2 | 0.61 |
| 4 | | | 0.87 | 126.6 | 146.8 | 21.3 | 0.59 |
| 5 | | | 0.33 | 48.1* | 132.6 | 19.2 | 0.25* |
| 6 | | | 0.50 | 72.2 | 132.8 | 19.3 | 0.37 |
| 7 | | | 0.92 | 132.6 | 148.8 | 21.6 | 0.61* |
| Average | 115.10 | 1.78 | 0.78 | 112.6 | 145.6 | 21.1 | 0.51 |
| Std. Dev. | 0 | 0 | 0.19 | 27.5 | 14.1 | 2.0 | 0.11 |

* Numbers not used in calculating Average and Standard Deviation.

Table A19

(Continued)

| Specimen No. | Fiber Area (μm^2) | (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 700°C, 8" Gage Length | | | | | | |
| 2BN4481 | 115.10 | 1.78 | 0.74 | 107.7 | 156.4 | 22.7 |
| 2 | | | 0.85 | 123.6 | 148.4 | 21.5 |
| 3 | | | 0.81 | 117.3 | 142.3 | 20.6* |
| 4 | | | 0.46 | 67.0* | 137.0 | 19.9* |
| 5 | | | 1.00 | 145.6* | 157.6 | 22.8 |
| 6 | | | 0.66 | 95.9 | 155.7 | 22.6 |
| 7 | | | 0.87 | 125.6 | 161.3 | 23.4* |
| 8 | | | 0.89 | 128.6 | 147.9 | 21.4 |
| 9 | | | 0.86 | 124.2 | 165.3 | 24.0* |
| 10 | | | 0.67 | 96.5 | 152.2 | 22.1 |
| Average | 115.10 | 1.78 | 0.79 | 114.9 | 153.0 | 22.2 |
| Std. Dev. | 0 | 0 | 0.09 | 13.2 | 4.2 | 0.6 |
| 700°C, 10" Gage Length | | | | | | |
| 2BN44101 | 115.10 | 1.78 | 0.69 | 99.7 | 149.6 | 21.7 |
| 2 | | | 0.95 | 137.0* | 164.4 | 23.8* |
| 3 | | | 0.67 | 97.1 | 131.4 | 19.0 |
| 4 | | | 0.43 | 61.8* | 155.1 | 22.5 |
| 5 | | | 0.50 | 72.4* | 144.8 | 21.0 |
| 7 | | | 0.63 | 91.7 | 127.9 | 18.5* |
| 8 | | | 0.80 | 116.7 | 128.8 | 18.7* |
| 9 | | | 0.66 | 96.3 | 146.1 | 21.2 |
| 10 | | | 0.74 | 107.7 | 142.9 | 20.7 |
| Average | 115.10 | 1.78 | 0.70 | 101.5 | 145.0 | 21.0 |
| Std. Dev. | 0 | 0 | 0.06 | 9.1 | 7.9 | 1.1 |
| 800°C, 8" Gage Length | | | | | | |
| 3BN4481 | 115.10 | 1.78 | 0.88 | 127.6 | 160.1 | 23.2 |
| 2 | | | 0.95 | 137.6 | 147.5 | 21.4 |
| 3 | | | 0.98 | 142.0 | 182.3 | 26.4* |
| 4 | | | 0.62 | 89.7 | 117.9 | 17.1 |
| 5 | | | 0.30 | 43.9* | 121.1 | 17.6 |
| 6 | | | 0.75 | 108.3 | 132.8 | 19.3 |
| 7 | | | 0.77 | 111.7 | 112.1 | 16.2* |
| 8 | | | 1.00 | 145.6 | 143.5 | 20.8 |
| Average | 115.10 | 1.78 | 0.85 | 123.2 | 137.2 | 19.9 |
| Std. Dev. | 0 | 0 | 0.14 | 20.6 | 16.3 | 2.4 |

* Numbers not used in calculating Average and Standard Deviation.

Table A19

(Continued)

| Specimen No. | Fiber Area (μm^2) | 10^{-7} in 2 | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|-------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 800°C, 10" Gage Length | | | | | | | |
| 3BN44103 | 115.10 | 1.78 | 0.77 | 111.1 | 131.0 | 19.0* | 0.58 |
| 4 | | | 0.94 | 135.8 | 154.9 | 22.5 | 0.60 |
| 5 | | | 0.88 | 126.8 | 152.2 | 22.1 | 0.57 |
| 6 | | | 0.65 | 93.9* | 154.3 | 22.4 | 0.42* |
| 7 | | | 0.81 | 117.5 | 143.5 | 20.8 | 0.56 |
| 9 | | | 1.00 | 144.8* | 163.7 | 23.7* | 0.61 |
| Average | 115.10 | 1.78 | 0.85 | 122.8 | 151.2 | 21.9 | 0.59 |
| Std. Dev. | 0 | 0 | 0.07 | 10.8 | 5.3 | 0.8 | 0.02 |

* Numbers not used in calculating Average and Standard Deviation.

Table A20

Individual Single Fiber Tensile Test Data for
Boron-Nitride Coated Nextel 480 at Room Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-----------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 1" Gage Length | | | | | | | |
| 0480101 | 106.58 | 1.65 | 1.86 | 270.0* | 171.8 | 24.9 | 1.08* |
| 2 | | | 1.36 | 197.0 | 198.0 | 28.7 | 0.69 |
| 3 | | | 0.70 | 102.0* | 179.4 | 26.0 | 0.39* |
| 4 | | | 0.91 | 132.0 | 167.0 | 24.2 | 0.55 |
| 5 | | | 0.88 | 128.0 | 172.5 | 25.0 | 0.51 |
| 6 | | | 1.61 | 234.0 | 164.2 | 23.8 | 0.98* |
| 7 | | | 1.35 | 196.0 | 171.1 | 24.8 | 0.79 |
| 8 | | | 1.64 | 237.0 | 171.1 | 24.8 | 0.96* |
| 10 | | | 0.99 | 143.0 | 185.6 | 26.9 | 0.53 |
| Average | 106.58 | 1.65 | 1.25 | 181.0 | 175.9 | 25.5 | 0.61 |
| Std. Dev. | 0 | 0 | 0.32 | 46.7 | 10.5 | 1.5 | 0.12 |
| 2" Gage Length | | | | | | | |
| 0480201 | 106.58 | 1.65 | 1.19 | 172.0* | 166.3 | 24.1 | 0.71* |
| 2 | | | 1.04 | 151.0 | 183.5 | 26.6 | 0.57 |
| 3 | | | 0.86 | 124.0 | 154.6 | 22.4 | 0.55 |
| 4 | | | 0.91 | 132.0 | 157.3 | 22.8 | 0.58 |
| 5 | | | 1.00 | 145.0 | 152.5 | 22.1 | 0.66 |
| 6 | | | 0.99 | 143.0 | 141.5 | 20.5 | 0.70 |
| 7 | | | 0.59 | 85.0* | 148.4 | 21.5 | 0.40* |
| 8 | | | 1.05 | 152.0 | 187.7 | 27.2 | 0.56 |
| 9 | | | 1.04 | 151.0 | 163.5 | 23.7 | 0.64 |
| 10 | | | 1.05 | 152.0 | 147.0 | 21.3 | 0.71 |
| Average | 106.58 | 1.65 | 0.99 | 144.0 | 160.2 | 23.2 | 0.62 |
| Std. Dev. | 0 | 0 | 0.07 | 10.5 | 15.3 | 2.2 | 0.06 |
| 4" Gage Length | | | | | | | |
| 0480402 | 106.58 | 1.65 | 1.21 | 176.0 | 240.8 | 34.9 | 0.50 |
| 3 | | | 1.56 | 226.0 | 271.2 | 39.3* | 0.58 |
| 4 | | | 1.02 | 148.0 | 180.8 | 26.2 | 0.57 |
| 5 | | | 1.08 | 157.0 | 176.6 | 25.6* | 0.61 |
| 6 | | | 1.46 | 211.0 | 197.3 | 28.6 | 0.74* |
| 7 | | | 1.08 | 157.0 | 213.9 | 31.0 | 0.51 |
| 8 | | | 1.83 | 265.0* | 228.4 | 33.1 | 0.80* |
| 9 | | | 0.86 | 124.0* | 193.9 | 28.1 | 0.44* |
| Average | 106.58 | 1.65 | 1.24 | 179.0 | 209.1 | 30.3 | 0.55 |
| Std. Dev. | 0 | 0 | 0.22 | 32.2 | 22.7 | 3.3 | 0.05 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A21

Individual Single Fiber Tensile Test Data for
Boron-Nitride Coated Nextel 480 at Elevated Temperature

| Specimen No. | Fiber Area (μm^2) | Fiber Area (10^{-7} in^2) | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|---|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 500°C, 8" Gage Length | | | | | | | |
| OBN4881A | 106.58 | 1.65 | 1.20 | 174.5* | 209.3 | 30.3 | 0.57 |
| 2 | | | 1.08 | 157.2 | 192.9 | 28.0 | 0.56 |
| 3 | | | 0.86 | 124.2 | 217.7 | 31.6* | 0.39 |
| 4A | | | 1.13 | 164.3* | 187.1 | 27.1 | 0.61* |
| 5 | | | 1.04 | 150.8 | 203.1 | 29.4 | 0.51 |
| 6 | | | 0.89 | 128.4 | 152.4 | 22.1* | 0.58 |
| 7 | | | 0.53 | 77.1* | 163.8 | 23.7* | 0.32* |
| 8 | | | 0.54 | 78.7* | 206.7 | 30.0 | 0.26* |
| 9 | | | 0.94 | 135.7 | 161.0 | 23.3* | 0.58 |
| 10 | | | 0.75 | 108.1 | 175.4 | 25.4 | 0.43 |
| Average | 106.58 | 1.65 | 0.92 | 134.1 | 195.7 | 28.4 | 0.52 |
| Std. Dev. | 0 | 0 | 0.12 | 18.0 | 13.1 | 0.9 | 0.08 |
| 500°C, 10" Gage Length | | | | | | | |
| OBN48101 | 106.58 | 1.65 | 0.98 | 142.2 | 206.5 | 29.9 | 0.47 |
| 2 | | | 0.46 | 66.8* | 192.0 | 27.8 | 0.24* |
| 3 | | | 1.17 | 170.1* | 190.9 | 27.7 | 0.61* |
| 4 | | | 1.16 | 168.0* | 229.6 | 33.3* | 0.51 |
| 5 | | | 0.84 | 121.9 | 195.6 | 28.4 | 0.43 |
| 6 | | | 0.81 | 118.0 | 175.1 | 25.4* | 0.47 |
| 7 | | | 0.72 | 103.8 | 193.6 | 28.1 | 0.37 |
| 8 | | | 0.96 | 138.7 | 187.7 | 27.2 | 0.51 |
| 9 | | | 0.74 | 107.7 | 193.0 | 28.0 | 0.38 |
| 10 | | | 0.77 | 112.0 | 193.2 | 28.0 | 0.40 |
| Average | 106.58 | 1.65 | 0.83 | 120.6 | 194.0 | 28.1 | 0.44 |
| Std. Dev. | 0 | 0 | 0.10 | 14.8 | 5.5 | 0.8 | 0.06 |
| 600°C, 8" Gage Length | | | | | | | |
| 1BN4881 | 106.58 | 1.65 | 0.76 | 109.8* | 168.4 | 24.4 | 0.45* |
| 2 | | | 0.87 | 126.0 | 154.6 | 22.4 | 0.56 |
| 3 | | | 1.00 | 144.7 | 139.0 | 20.1* | 0.72* |
| 4 | | | 0.82 | 118.5 | 153.9 | 22.3 | 0.53 |
| 5 | | | 0.94 | 135.7 | 180.5 | 26.2* | 0.52 |
| 6 | | | 1.06 | 153.4* | 167.6 | 24.3 | 0.63 |
| Average | 106.58 | 1.65 | 0.91 | 131.2 | 161.1 | 23.3 | 0.56 |
| Std. Dev. | 0 | 0 | 0.08 | 11.4 | 8.0 | 1.2 | 0.05 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A21

(Continue)

| Specimen No. | Fiber Area (μm^2) | 10^{-7} in^2 | Tensile Strength (GPa) | Tensile Strength (ksi) | Tensile Modulus (GPa) | Tensile Modulus (Msi) | Ultimate Strain (percent) |
|-------------------------------|-----------------------------------|-----------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| 600°C, 10" Gage Length | | | | | | | |
| 1BN48101 | 106.58 | 1.65 | 1.16 | 168.2 | 232.1 | 33.6 | 0.50 |
| 2 | | | 0.64 | 92.6 | 182.6 | 26.5 | 0.35 |
| 3 | | | 0.66 | 96.1 | 165.7 | 24.0* | 0.40 |
| 4 | | | 1.22 | 176.6* | 267.8 | 38.8* | 0.45 |
| 5 | | | 0.42 | 60.5* | 185.6 | 26.9 | 0.22* |
| 6 | | | 0.65 | 94.6 | 191.9 | 27.8 | 0.34 |
| 7 | | | 1.13 | 163.9 | 188.5 | 27.3 | 0.60* |
| Average | 106.58 | 1.65 | 0.85 | 123.1 | 196.1 | 28.4 | 0.41 |
| Std. Dev. | 0 | 0 | 0.27 | 39.3 | 20.4 | 3.0 | 0.07 |
| 700°C, 8" Gage Length | | | | | | | |
| 2BN4881 | 106.58 | 1.65 | 1.49 | 215.8* | 283.7 | 41.1* | 0.52* |
| 2 | | | 1.04 | 151.0 | 254.1 | 36.8 | 0.41 |
| 3 | | | 0.65 | 94.8* | 229.4 | 33.3 | 0.28* |
| 4 | | | 0.86 | 124.9 | 236.1 | 34.2 | 0.36 |
| 5 | | | 0.64 | 92.8* | 228.7 | 33.2 | 0.28* |
| 6 | | | 0.63 | 91.5* | 175.5 | 25.4* | 0.36 |
| 7 | | | 1.24 | 179.8 | 285.2 | 41.3* | 0.44 |
| 8 | | | 1.06 | 153.4 | 264.5 | 38.3 | 0.40 |
| 9 | | | 0.99 | 143.2 | 224.6 | 32.6 | 0.44 |
| 10 | | | 1.19 | 172.3 | 273.3 | 39.6 | 0.44 |
| Average | 106.58 | 1.65 | 1.06 | 154.1 | 244.4 | 35.4 | 0.41 |
| Std. Dev. | 0 | 0 | 0.14 | 19.9 | 19.4 | 2.8 | 0.04 |
| 700°C, 10" Gage Length | | | | | | | |
| 2BN48102 | 106.58 | 1.65 | 0.97 | 140.0 | 207.8 | 30.1 | 0.47 |
| 3 | | | 0.78 | 112.6* | 207.3 | 30.0 | 0.37* |
| 4 | | | 0.95 | 137.0 | 217.3 | 31.5* | 0.44 |
| 6 | | | 0.91 | 131.8 | 204.4 | 29.6 | 0.44 |
| 7 | | | 1.03 | 149.3* | 168.8 | 24.5* | 0.61* |
| 8 | | | 0.85 | 123.8 | 189.9 | 27.5 | 0.45 |
| 9 | | | 0.76 | 109.8* | 159.5 | 23.1* | 0.47 |
| Average | 106.58 | 1.65 | 0.92 | 133.2 | 202.3 | 29.3 | 0.45 |
| Std. Dev. | 0 | 0 | 0.05 | 7.1 | 8.4 | 1.2 | 0.02 |

* Numbers not used in calculating the Average or Standard Deviation.

Table A21

(Continued)

| Specimen No. | Fiber Area | | Tensile Strength | | Tensile Modulus | | Ultimate Strain |
|-------------------------------|---------------------|---------------------------|------------------|--------|-----------------|-------|-----------------|
| | (μm^2) | (10^{-7} in^2) | (GPa) | (ksi) | (GPa) | (Msi) | (percent) |
| 800°C, 8" Gage Length | | | | | | | |
| 3BN4881A | 106.58 | 1.65 | 0.73 | 105.5* | 179.3 | 26.0 | 0.41* |
| 2 | | | 1.22 | 177.0* | 199.4 | 28.9* | 0.61 |
| 3 | | | 0.99 | 143.0 | 188.0 | 27.2 | 0.52 |
| 4A | | | 1.25 | 181.6* | 155.4 | 22.5* | 0.81* |
| 5 | | | 0.74 | 107.7* | 169.8 | 24.6 | 0.44 |
| 6 | | | 1.13 | 163.9 | 172.4 | 25.0 | 0.66 |
| 7A | | | 1.01 | 145.8 | 201.2 | 29.2* | 0.50 |
| 8 | | | 0.76 | 109.8 | 151.6 | 22.0* | 0.50 |
| Average | 106.58 | 1.65 | 1.04 | 150.9 | 177.3 | 25.7 | 0.54 |
| Std. Dev. | 0 | 0 | 0.08 | 11.3 | 8.1 | 1.2 | 0.08 |
| 800°C, 10" Gage Length | | | | | | | |
| 3BN48103A | 106.58 | 1.65 | 1.06 | 152.9 | 234.5 | 34.0* | 0.45 |
| 4 | | | 0.62 | 89.8* | 213.7 | 31.0 | 0.29* |
| 5 | | | 1.11 | 161.5 | 187.3 | 27.2 | 0.59 |
| 6A | | | 1.03 | 149.0 | 197.8 | 28.7 | 0.52 |
| 7 | | | 1.11 | 161.5 | 181.3 | 26.3 | 0.61 |
| 8 | | | 0.97 | 140.0 | 162.4 | 23.5* | 0.59 |
| 9A | | | 1.39 | 200.7* | 213.1 | 30.9 | 0.65 |
| Average | 106.58 | 1.65 | 1.06 | 153.0 | 198.6 | 28.8 | 0.57 |
| Std. Dev. | 0 | 0 | 0.06 | 9.1 | 14.7 | 2.1 | 0.07 |

* Numbers not used in calculating the Average or Standard Deviation.

Appendix B
Individual Single Fiber Tensile Creep Test Data

Table B1

Individual Single Fiber High Temperature
Tensile Creep Data for Nixel 440, Uncoated

| Specimen No. | Test Temperature (°C) | Strain Rate From $\frac{1}{2}$ Hour to 1 Hour (10^{-6} /hour) | Strain Rate From $\frac{1}{2}$ Hour to End of Test (10^{-6} /hour) |
|-----------------|-----------------------------|---|--|
| DT3501 | 500 | 468 | 51 |
| DT3502 | | 549 | 85 |
| DT3504 | | 555 | 20 |
| | Average | 524 | 52 |
| | Std. Dev. | 49 | 33 |
| DT3601 | 600 | 138 | 95 |
| DT3602 | | 147 | 6 |
| DT3606 | | 384 | 50 |
| | Average | 223 | 50 |
| | Std. Dev. | 140 | 44 |
| DT3702 | 700 | 1110* | 214 |
| DT3704 | | 61 | -57* |
| DT3705 | | 48 | 165 |
| | Average | 54 | 190 |
| | Std. Dev. | 9 | 35 |
| DT3803 | 800 | 861 | 285 |
| DT3808 | | 179 | 226 |
| DT3809 | | 578 | 492 |
| | Average | 539 | 334 |
| | Std. Dev. | 343 | 140 |

* Numbers not used in calculating the Average or the Standard Deviation.

Table B2

Individual Single Fiber High Temperature Tensile
Creep Data for Boron-Nitride Coated Nexel 312

| Specimen No. | Test Temperature (°C) | Strain Rate From $\frac{1}{2}$ Hour to 1 Hour (10^{-6} /hour) | Strain Rate From $\frac{1}{2}$ Hour to End of Test (10^{-6} /hour) |
|-----------------|-----------------------------|---|--|
| DT2501 | 500 | 778 | 93 |
| DT2502 | | 483 | 79 |
| DT2505 | | 279 | - |
| | Average | 513 | 77 |
| | Std. Dev. | 251 | 17 |
| DT2601 | 600 | 431 | 116 |
| DT2602 | | 167 | 19 |
| DT2604 | | 701 | 181 |
| DT2605 | | 516 | 122 |
| | Average | 454 | 110 |
| | Std. Dev. | 222 | 67 |
| DT2702 | 700 | 456 | 136 |
| DT2704 | | 676 | 159 |
| DT2705 | | 757 | 188 |
| | Average | 630 | 161 |
| | Std. Dev. | 156 | 26 |
| DT2801 | 800 | 344 | -19* |
| DT2803 | | 1010 | 216 |
| DT2806 | | 583 | 161 |
| | Average | 646 | 188 |
| | Std. Dev. | 338 | 39 |

* Numbers not used in calculating the Average or the Standard Deviation.

Table B3

Individual Single Fiber High Temperature Tensile Creep Data for Boron-Nitride Coated Nexel 440

| Specimen No. | Test Temperature (°C) | Strain Rate From $\frac{1}{2}$ Hour to 1 Hour ($10^{-6}/\text{hour}$) | Strain Rate From $\frac{1}{2}$ Hour to End of Test ($10^{-6}/\text{hour}$) |
|--------------|-----------------------|---|--|
| DT4506 | 500 | -74* | 39 |
| DT4512 | | 42 | 45 |
| DT4513 | | 304 | -6* |
| | Average | 173 | 42 |
| | Std. Dev. | 185 | 4 |
| DT4601 | 600 | 350 | 55 |
| DT4603 | | 319 | 106 |
| DT4604 | | 171 | 78 |
| | Average | 280 | 80 |
| | Std. Dev. | 96 | 26 |
| DT4701 | 700 | 744 | 146 |
| DT4702 | | 723 | 133 |
| DT4703 | | 311 | 34 |
| | Average | 593 | 104 |
| | Std. Dev. | 244 | 61 |
| DT4806 | 800 | 209 | 175 |
| DT4811 | | 35* | -73* |
| DT4812 | | 659 | 68 |
| | Average | 434 | 122 |
| | Std. Dev. | 318 | 76 |

* Numbers not used in calculating the Average or the Standard Deviation.

Table B4

Individual Single Fiber High Temperature Tensile Creep Data for Boron-Nitride Coated Nexel 480

| Specimen No. | Test Temperature (°C) | Strain Rate From $\frac{1}{2}$ Hour to 1 Hour ($10^{-6}/\text{hour}$) | Strain Rate From $\frac{1}{2}$ Hour to End of Test ($10^{-6}/\text{hour}$) |
|--------------|-----------------------|---|--|
| DT5503 | 500 | 38 | 17 |
| DT5504 | | 601 | 118 |
| DT5506 | | 197 | 23 |
| | Average | 279 | 53 |
| | Std. Dev. | 290 | 56 |
| DT5601 | 600 | 315 | 104 |
| DT5602 | | 165 | 16 |
| DT5604 | | 250 | 60 |
| DT5605 | | 391 | -7* |
| | Average | 280 | 60 |
| | Std. Dev. | 96 | 44 |
| DT5701 | 700 | 118 | 28 |
| DT5703 | | 293 | 129 |
| DT5705 | | -107* | 32 |
| | Average | 206 | 63 |
| | Std. Dev. | 124 | 57 |
| DT5801 | 800 | 405 | 91 |
| DT5804 | | 509 | -105* |
| DT5805 | | 398 | -43* |
| DT5806 | | 37* | -49* |
| | Average | 437 | 91 |
| | Std. Dev. | 62 | - |

* Numbers not used in calculating the Average or the Standard Deviation.

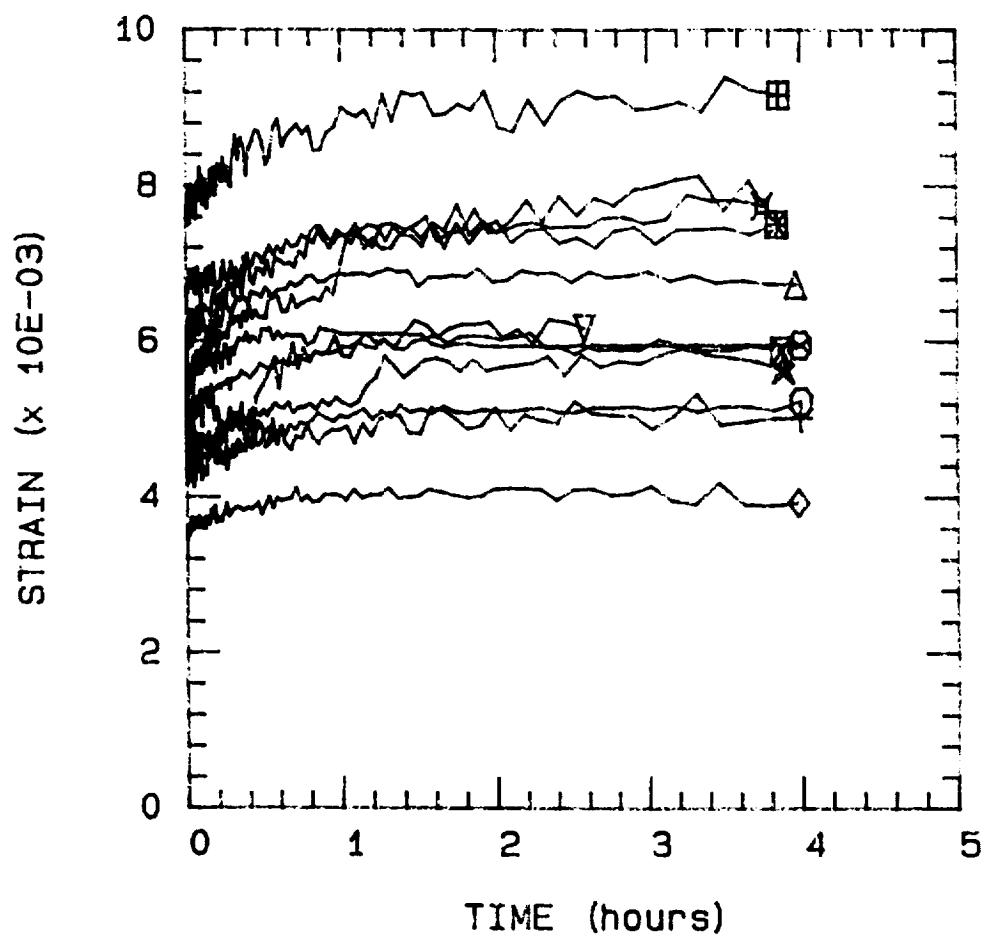
Table B5

Individual Single Fiber High Temperature Tensile Creep Data for Boron-Nitride Coated Nicalon NLM-102

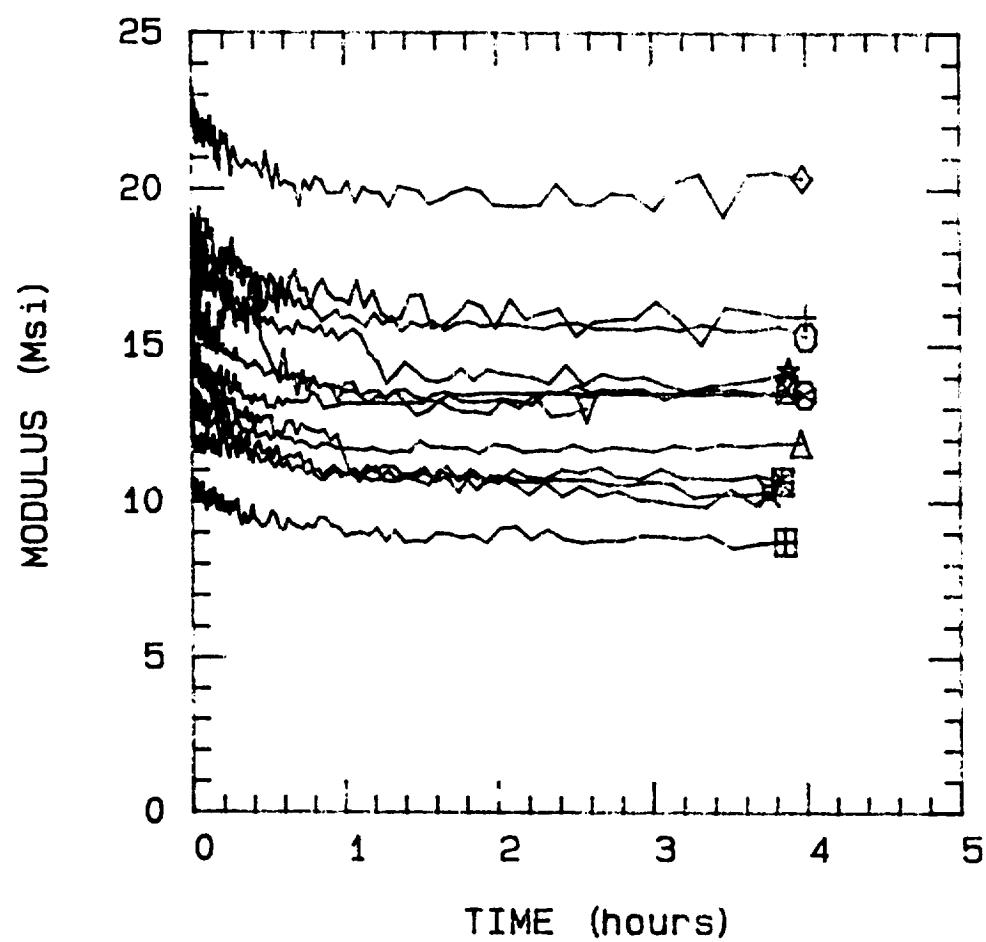
| Specimen No. | Test Temperature (°C) | Strain Rate From $\frac{1}{2}$ Hour to 1 Hour ($10^{-6}/\text{hour}$) | Strain Rate From $\frac{1}{2}$ Hour to End of Test ($10^{-6}/\text{hour}$) |
|--------------|-----------------------|---|--|
| DT1507 | 500 | 1150 | 298 |
| DT1508 | | 606 | 172 |
| DT1510 | | -198* | -14* |
| | Average | 878 | 235 |
| | Std. Dev. | 385 | 89 |
| DT1602 | 600 | 1390* | 291 |
| DT1603 | | 698 | -90* |
| DT1605 | | 289 | 13* |
| DT1607 | | 587 | 156 |
| | Average | 525 | 224 |
| | Std. Dev. | 212 | 95 |
| DT1702 | 700 | 303 | 84 |
| DT1703 | | 468 | 47 |
| DT1706 | | 570 | 143 |
| | Average | 447 | 92 |
| | Std. Dev. | 135 | 48 |
| DT1801 | 800 | 475 | 73 |
| DT1802 | | -18* | -1* |
| DT1803 | | -427* | 155 |
| | Average | 475 | 114 |
| | Std. Dev. | - | 58 |

* Numbers not used in calculating the Average or the Standard Deviation.

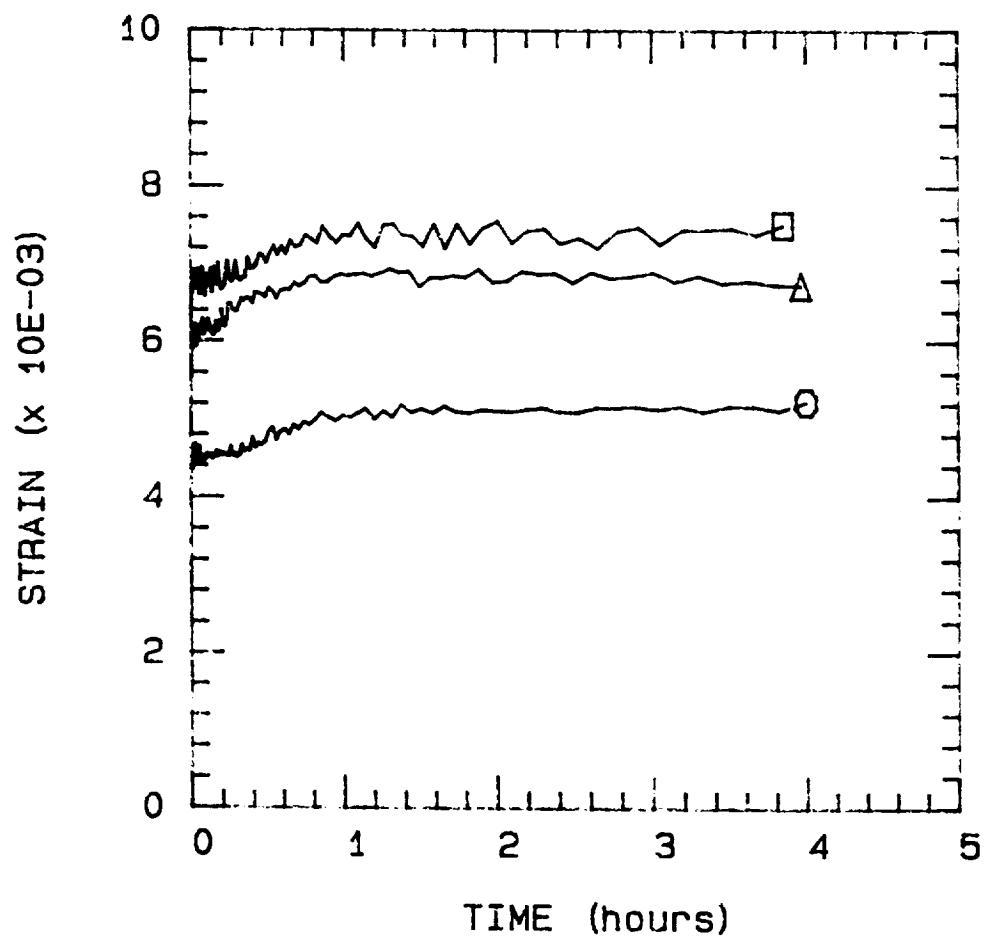
NEXTEL 440



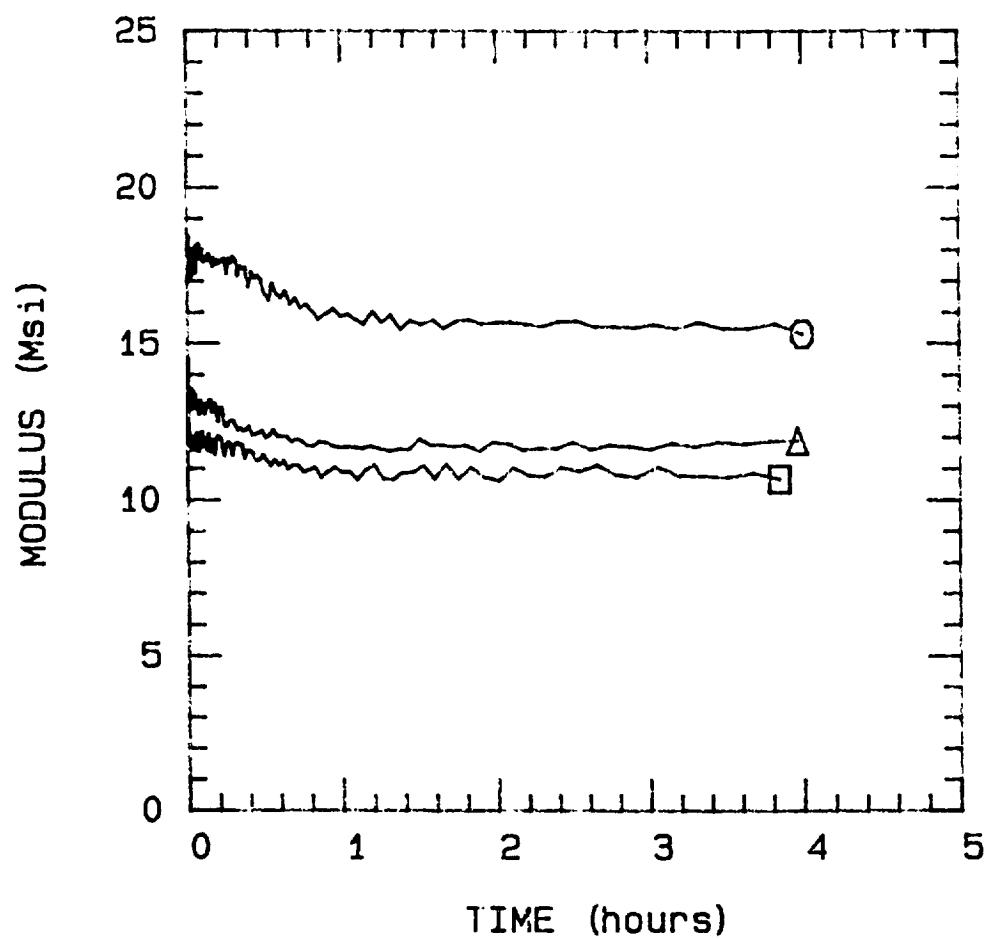
NEXTEL 440



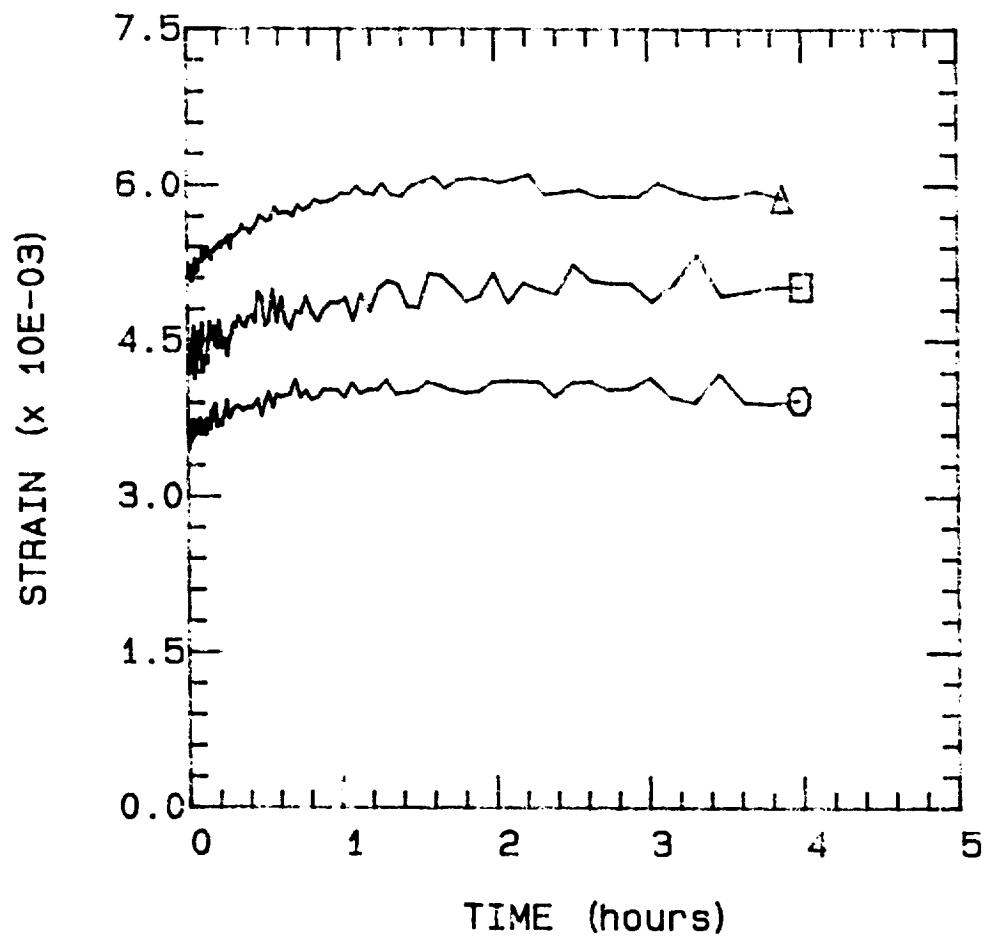
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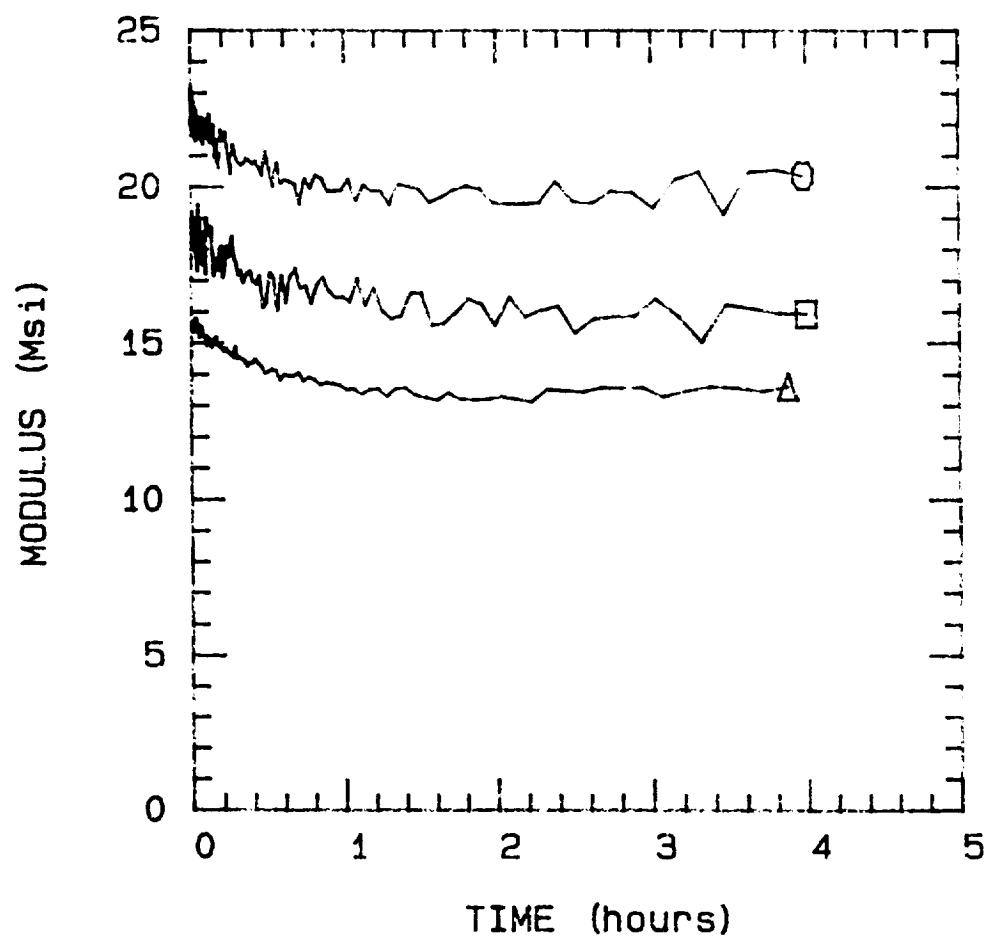
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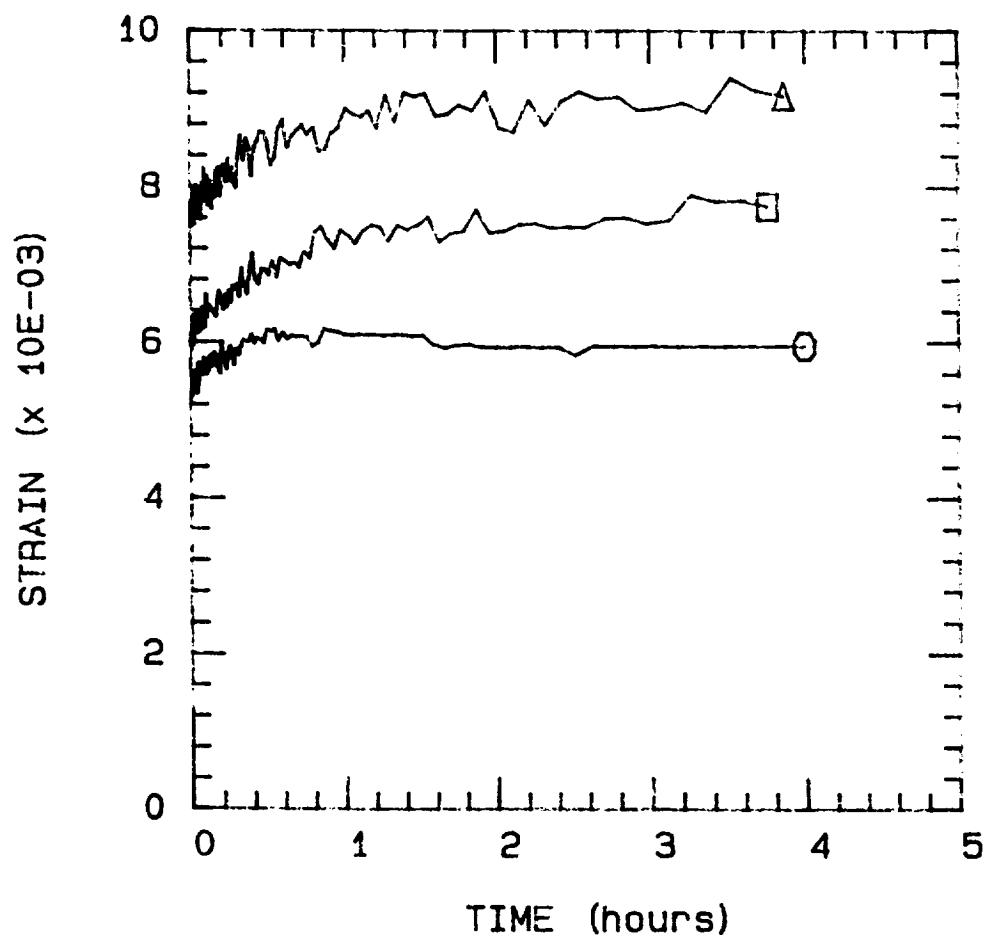
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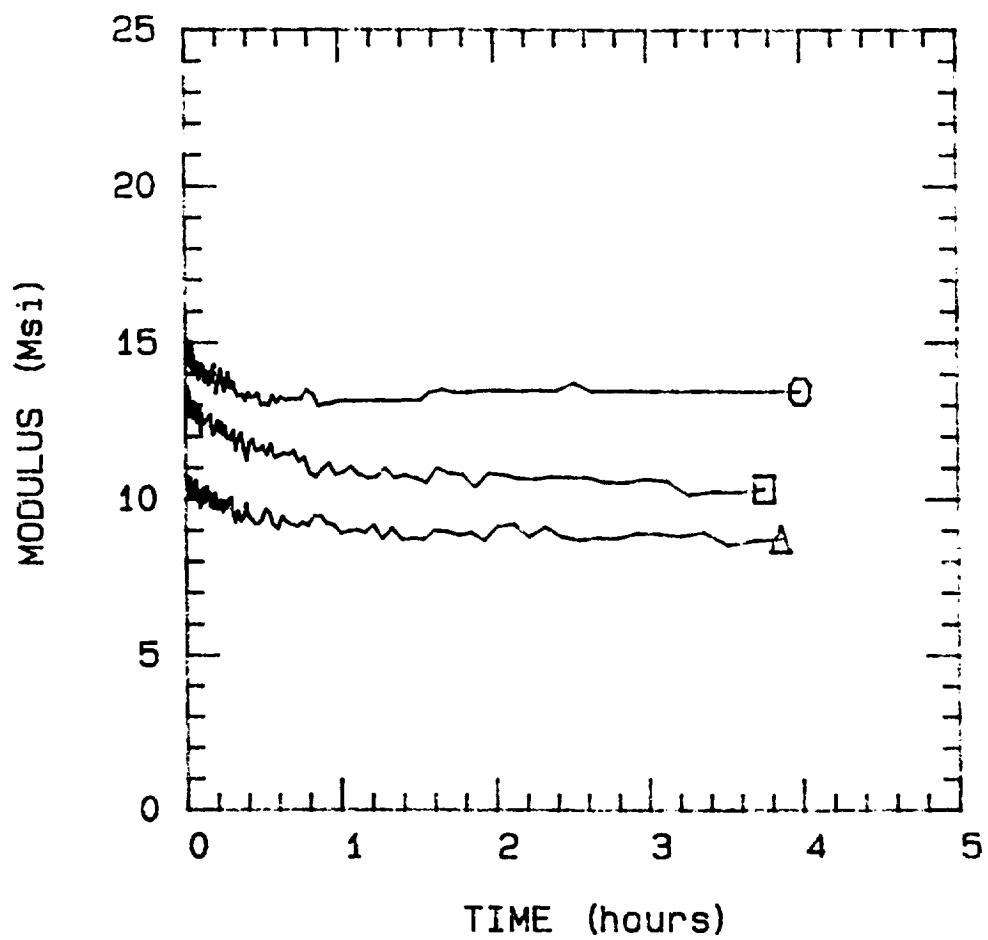
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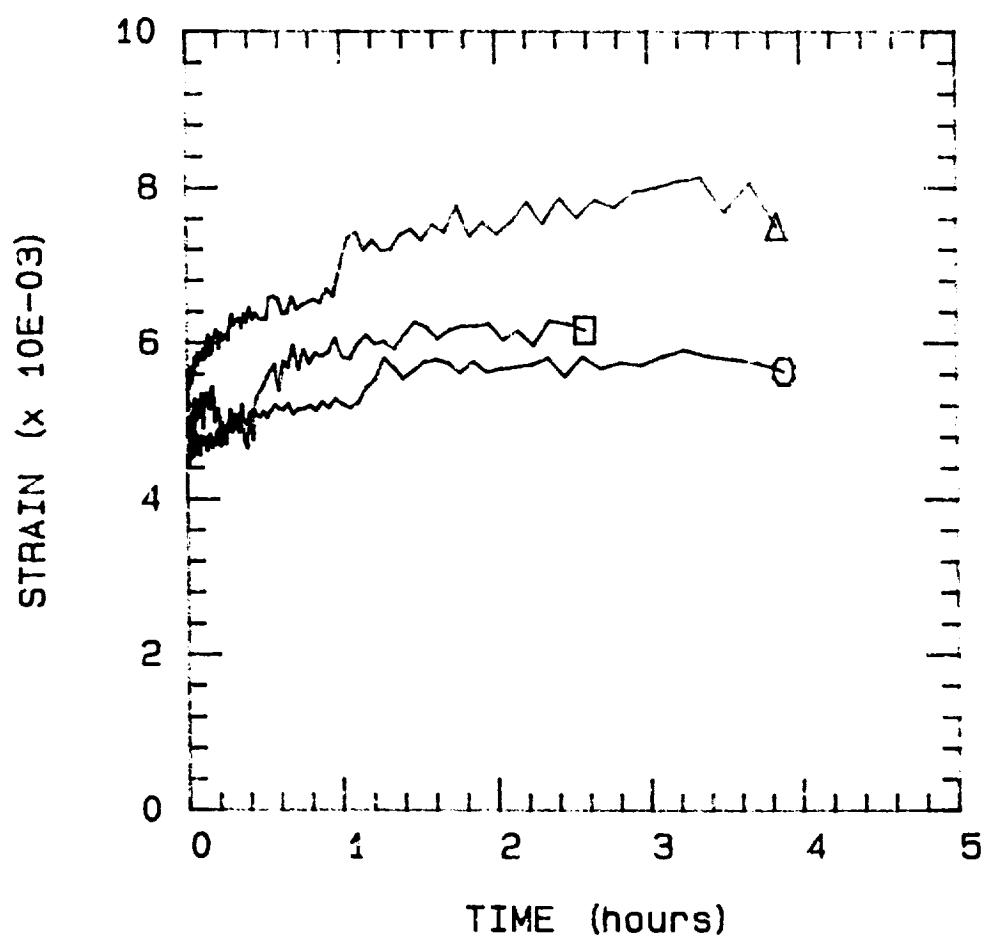
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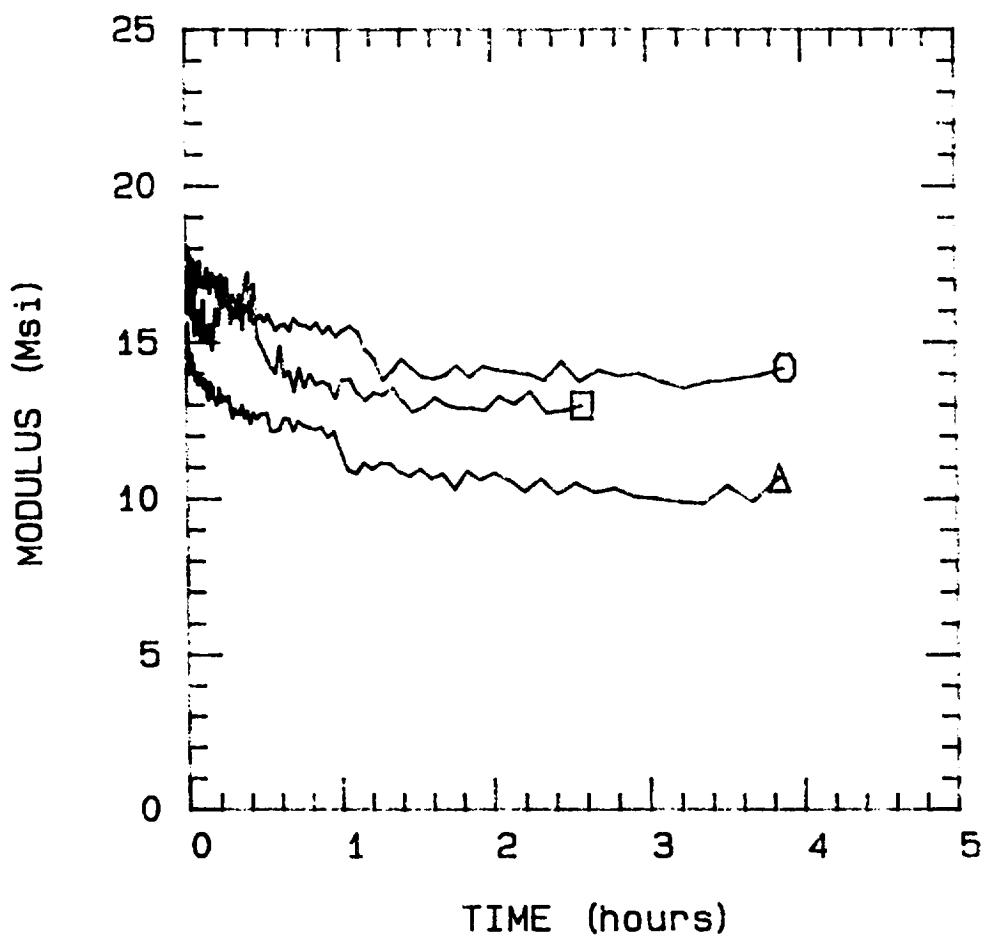
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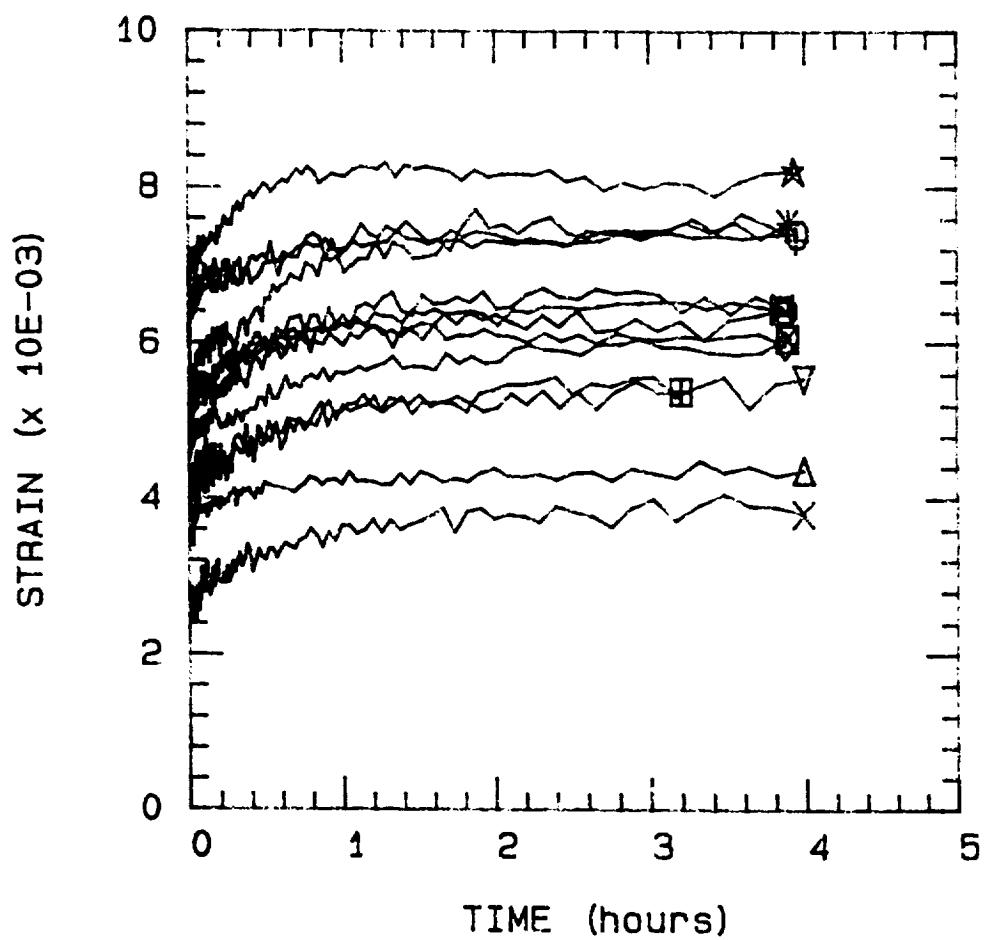
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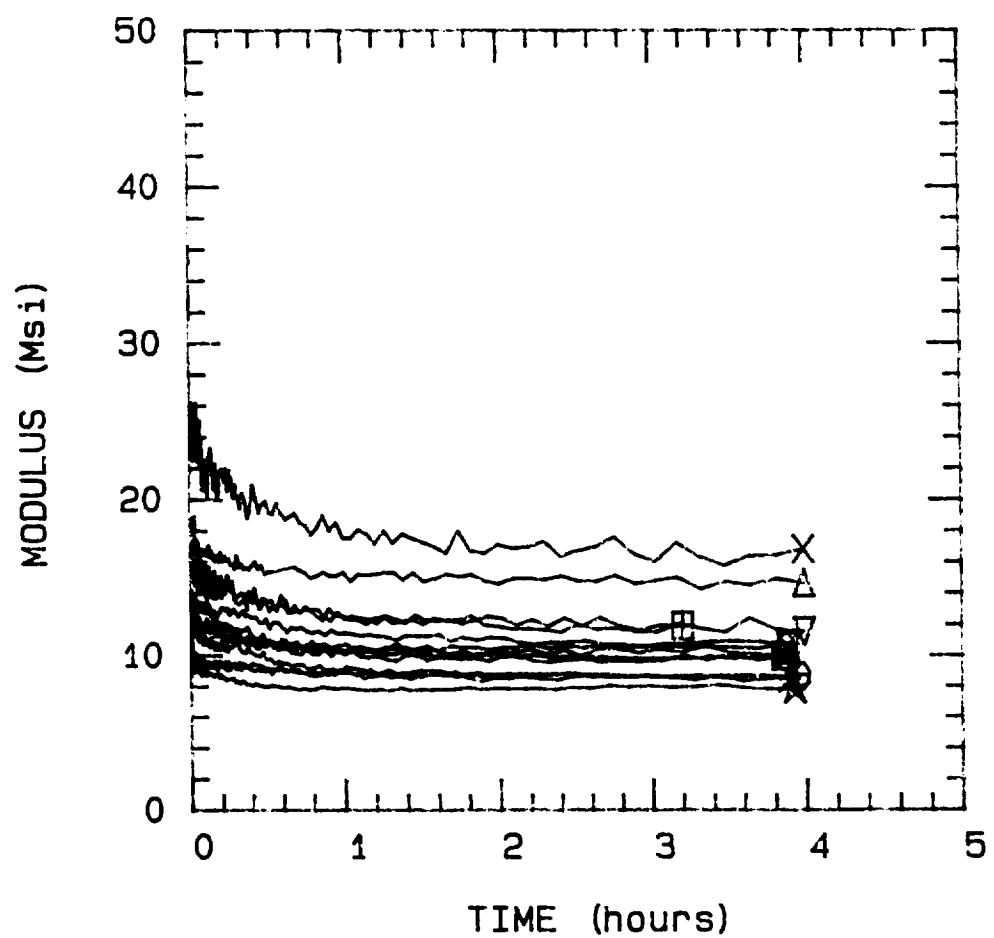
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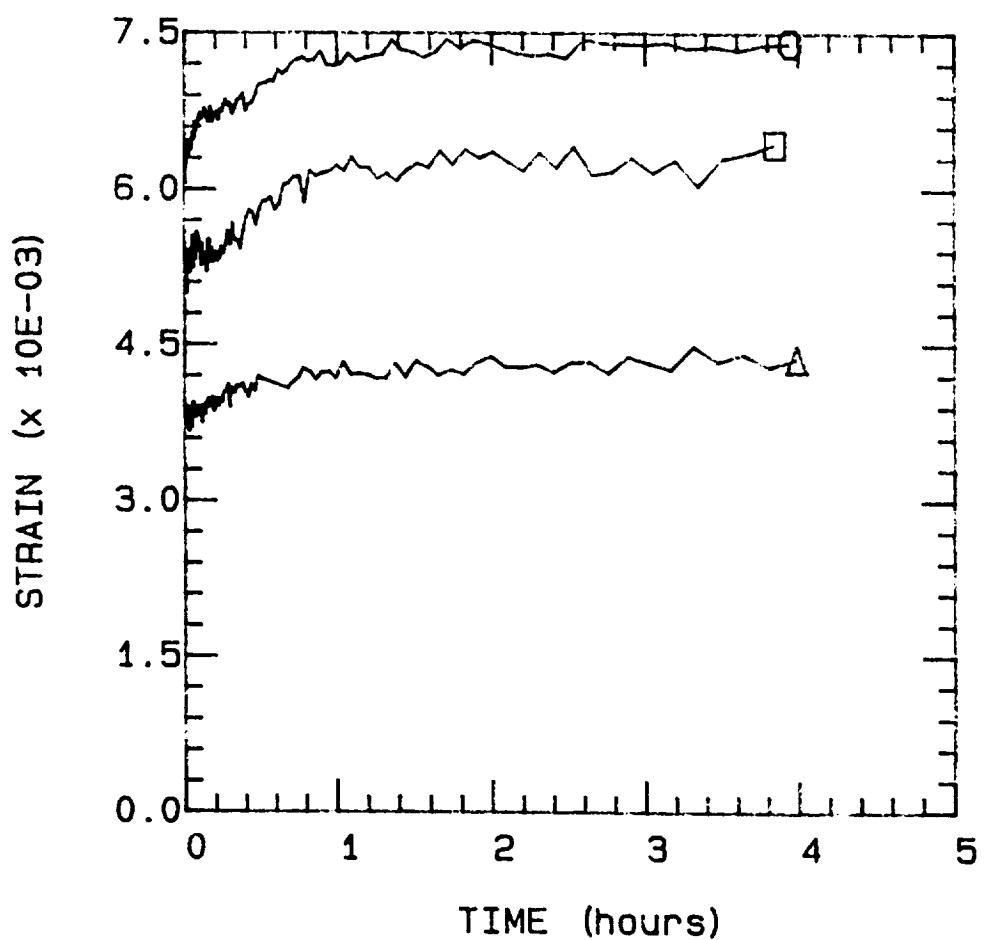
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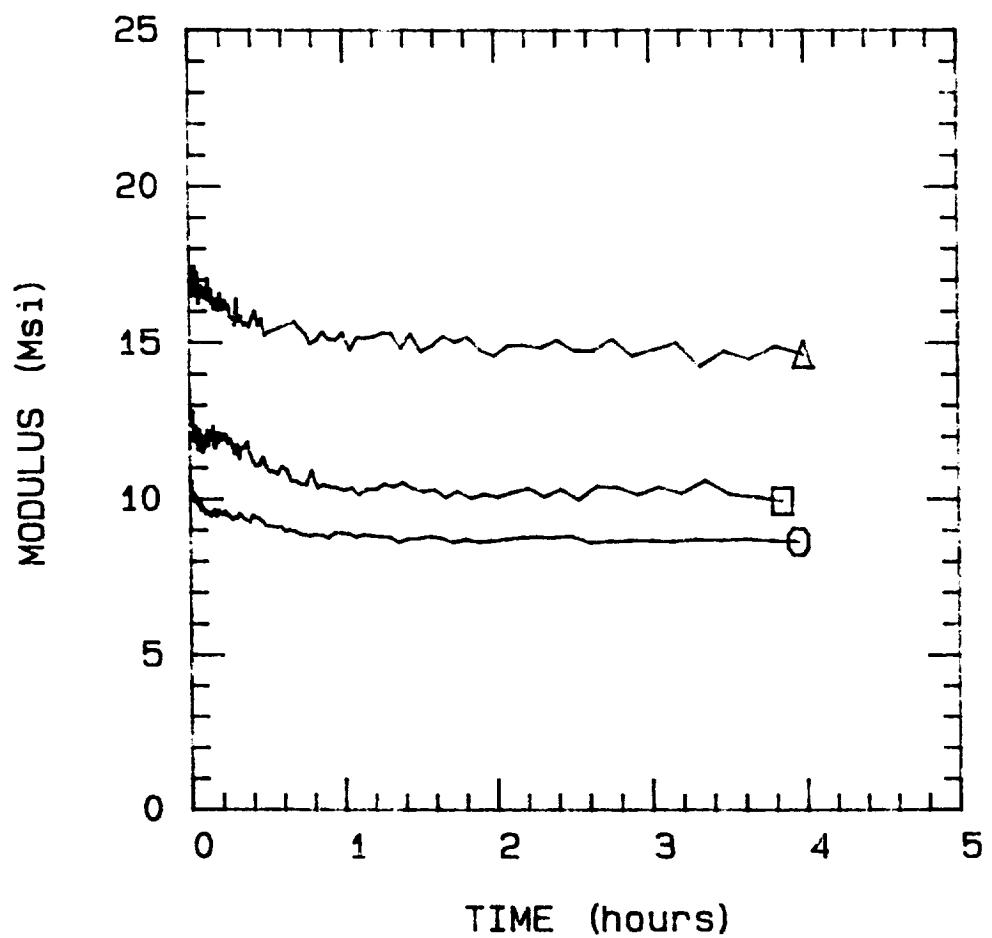
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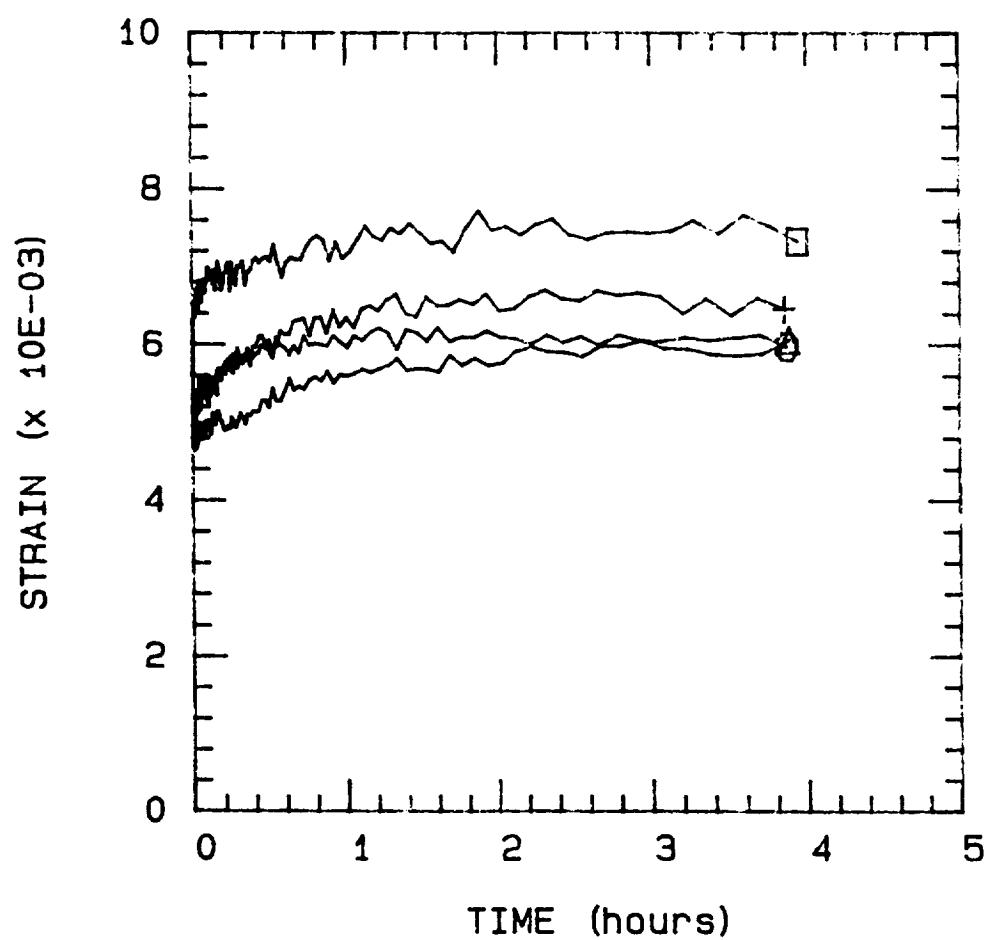
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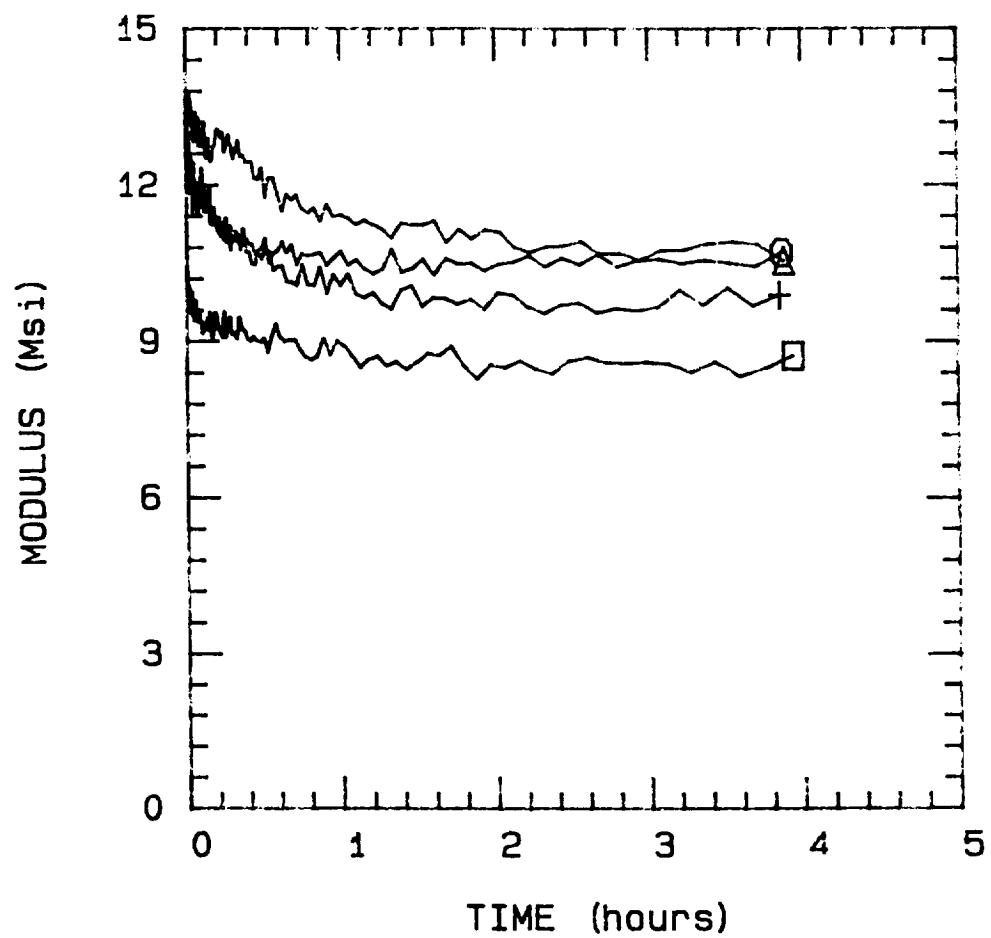
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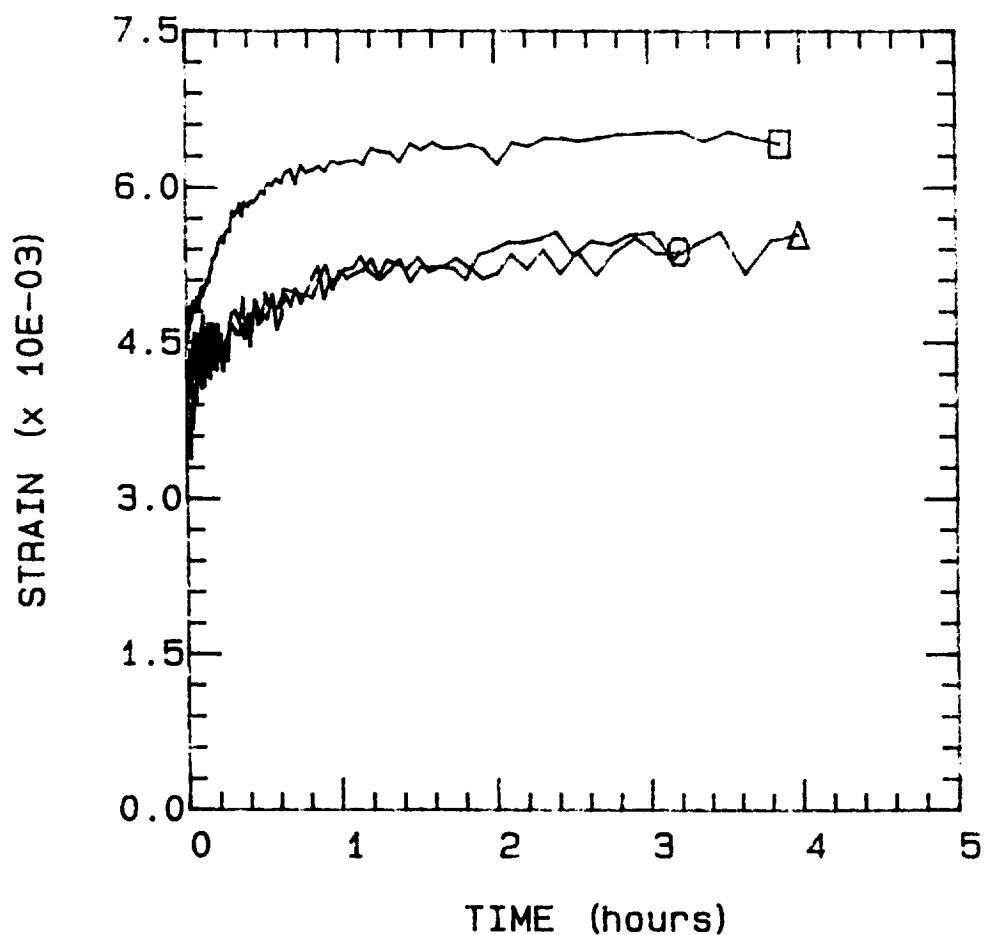
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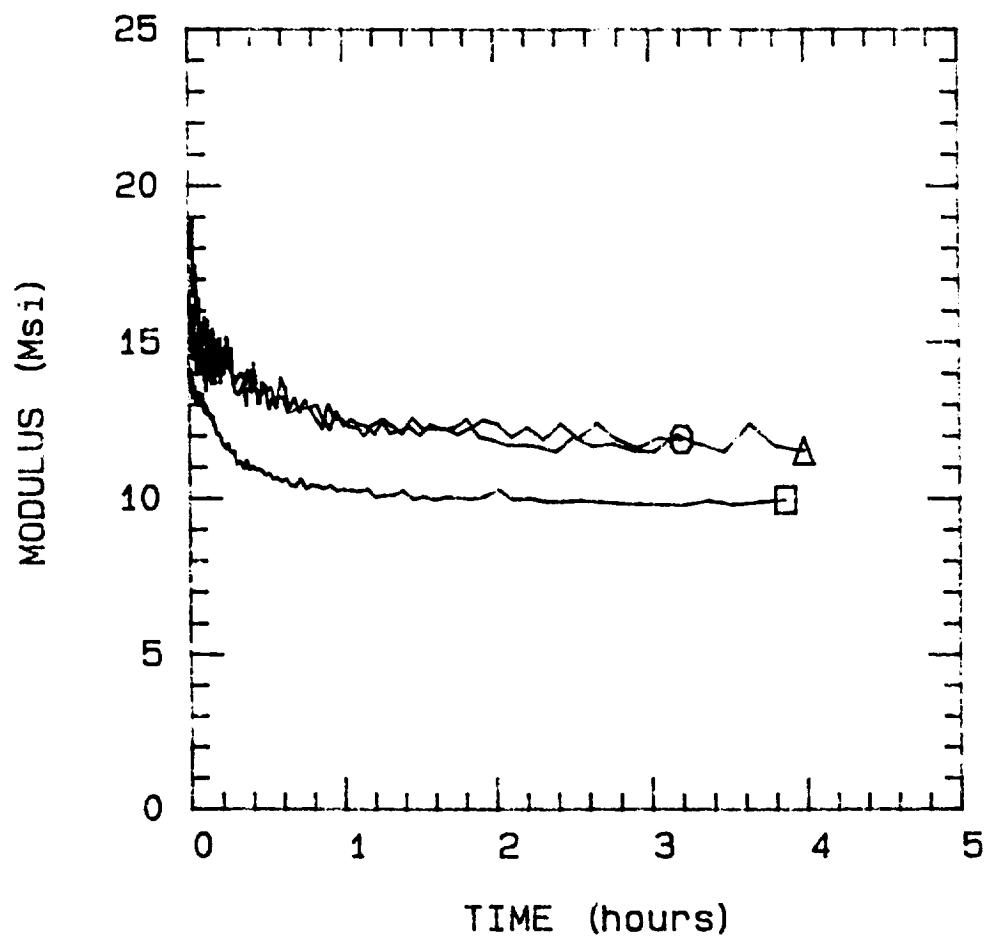
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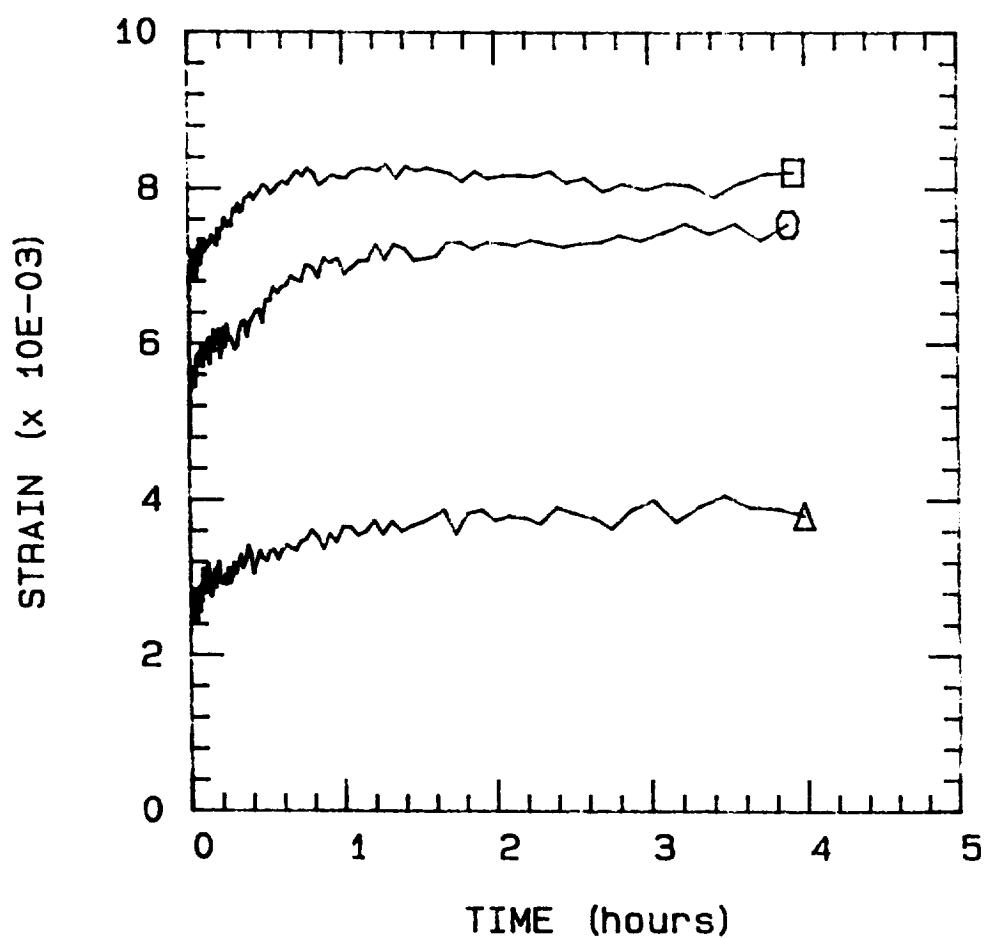
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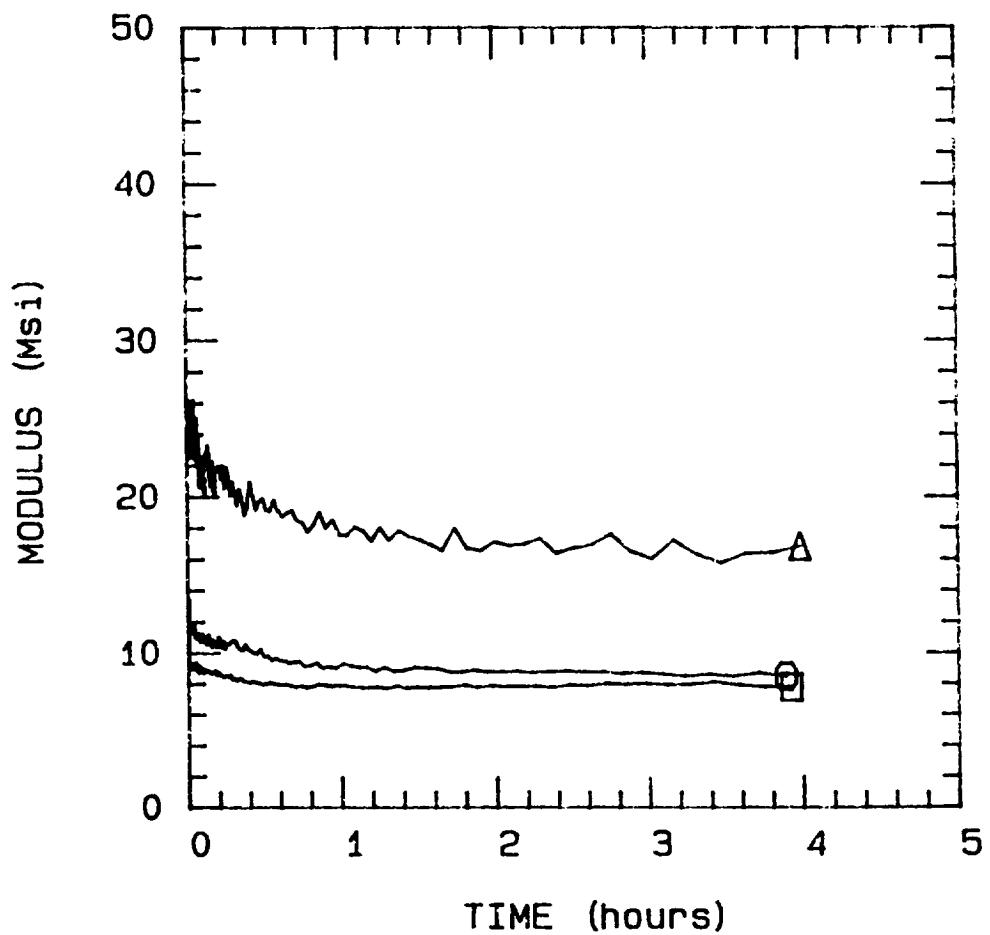
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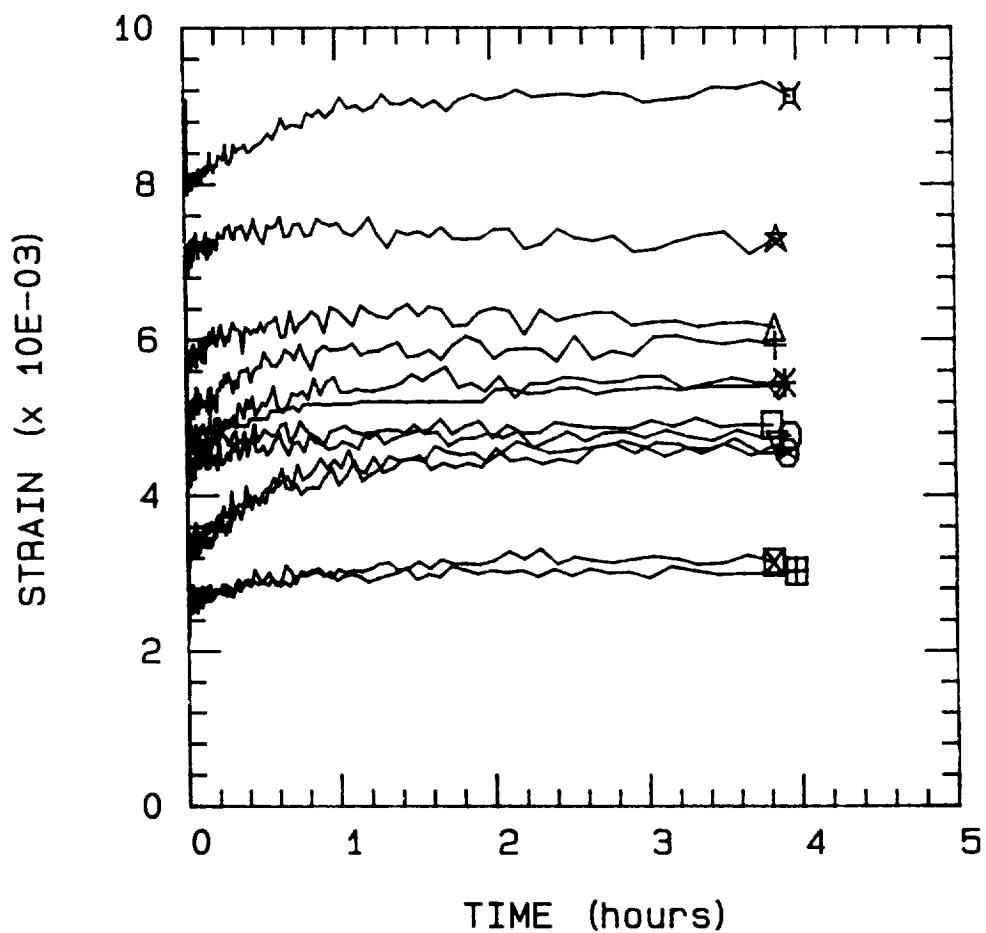
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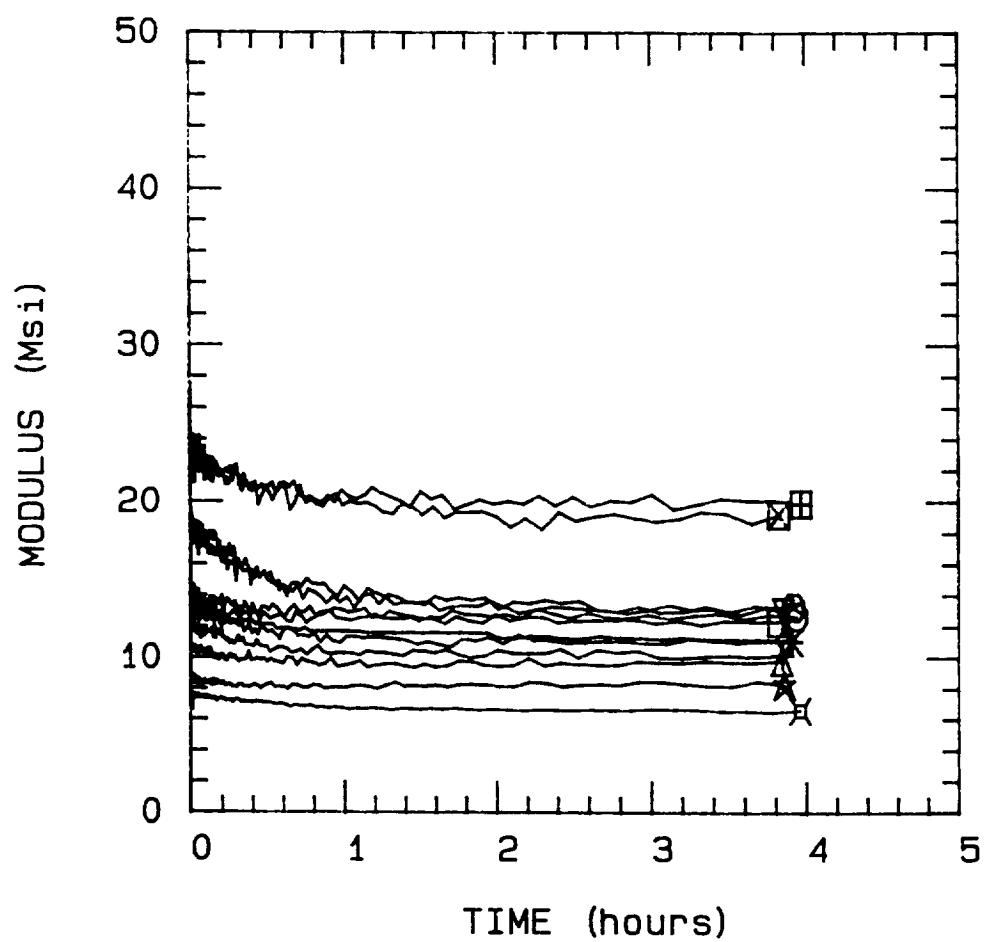
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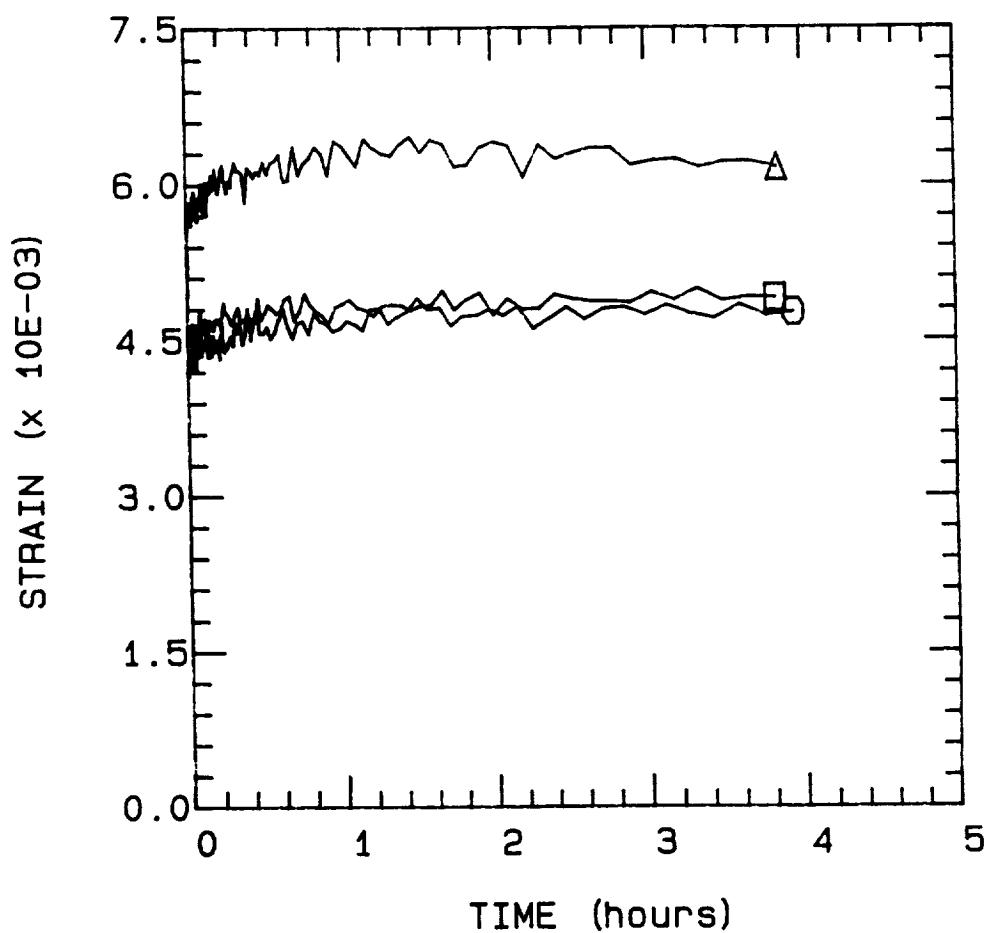
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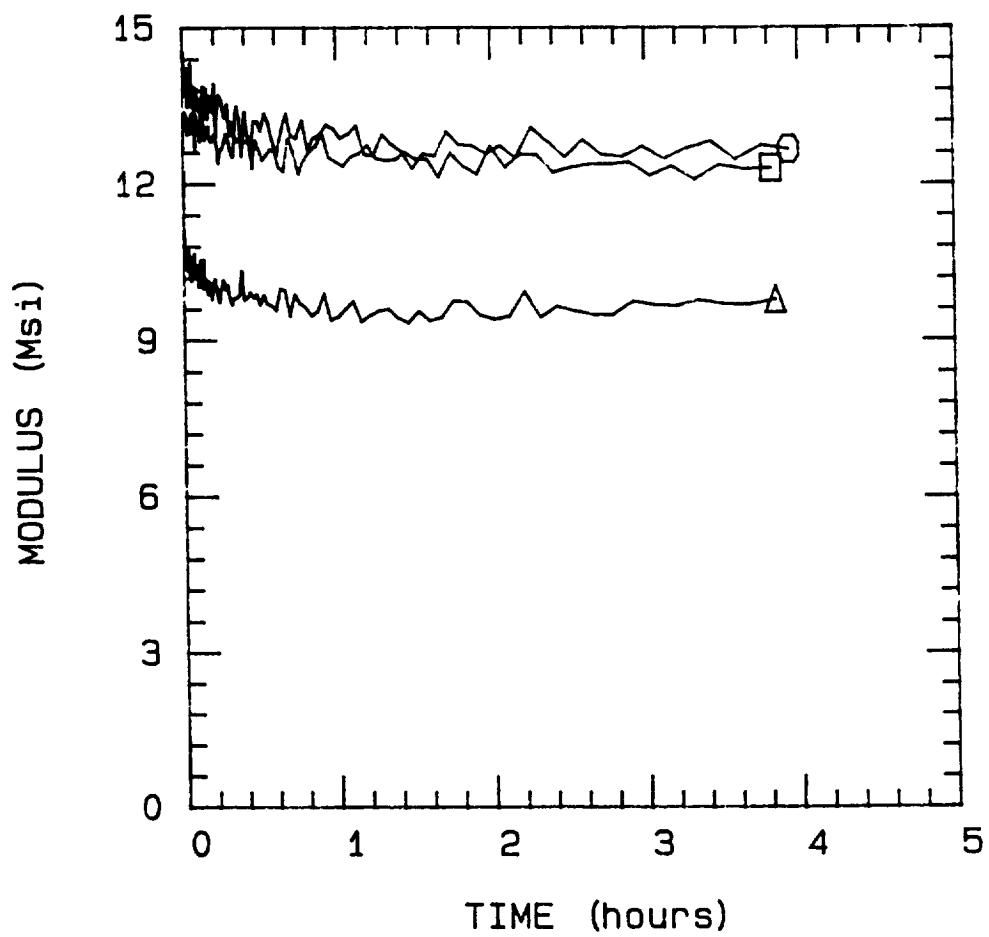
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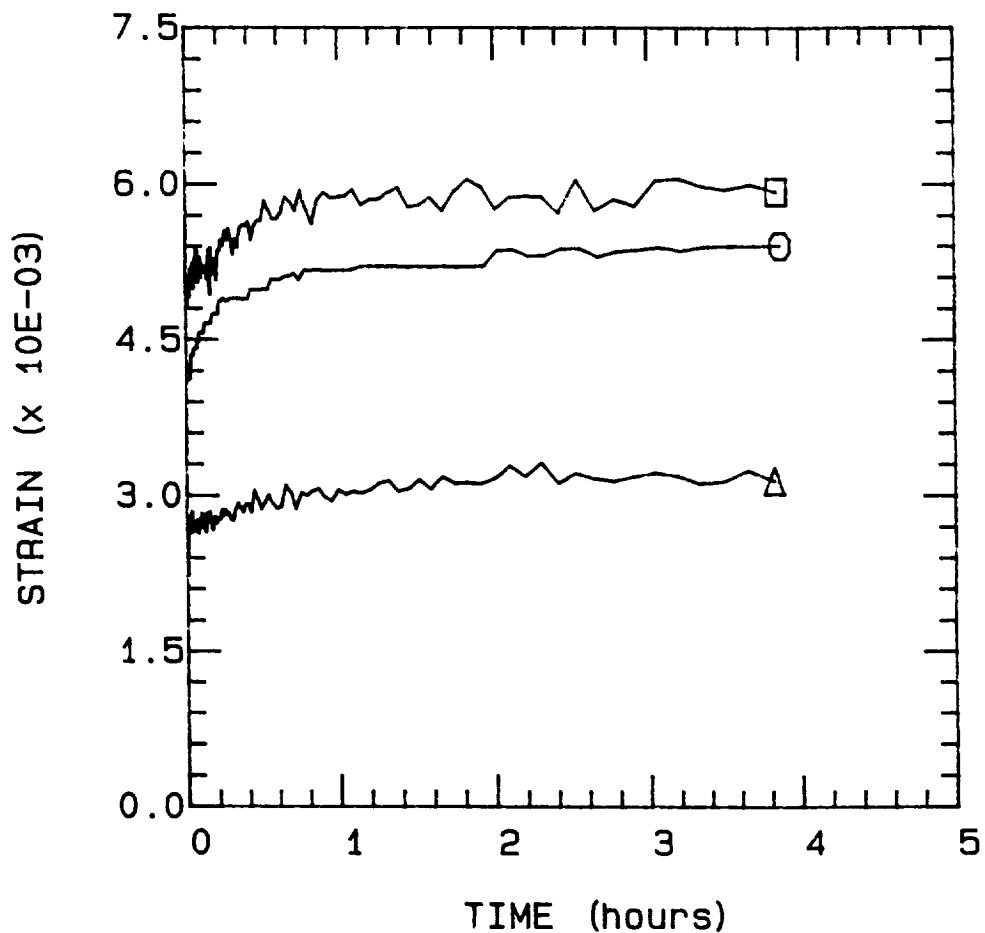
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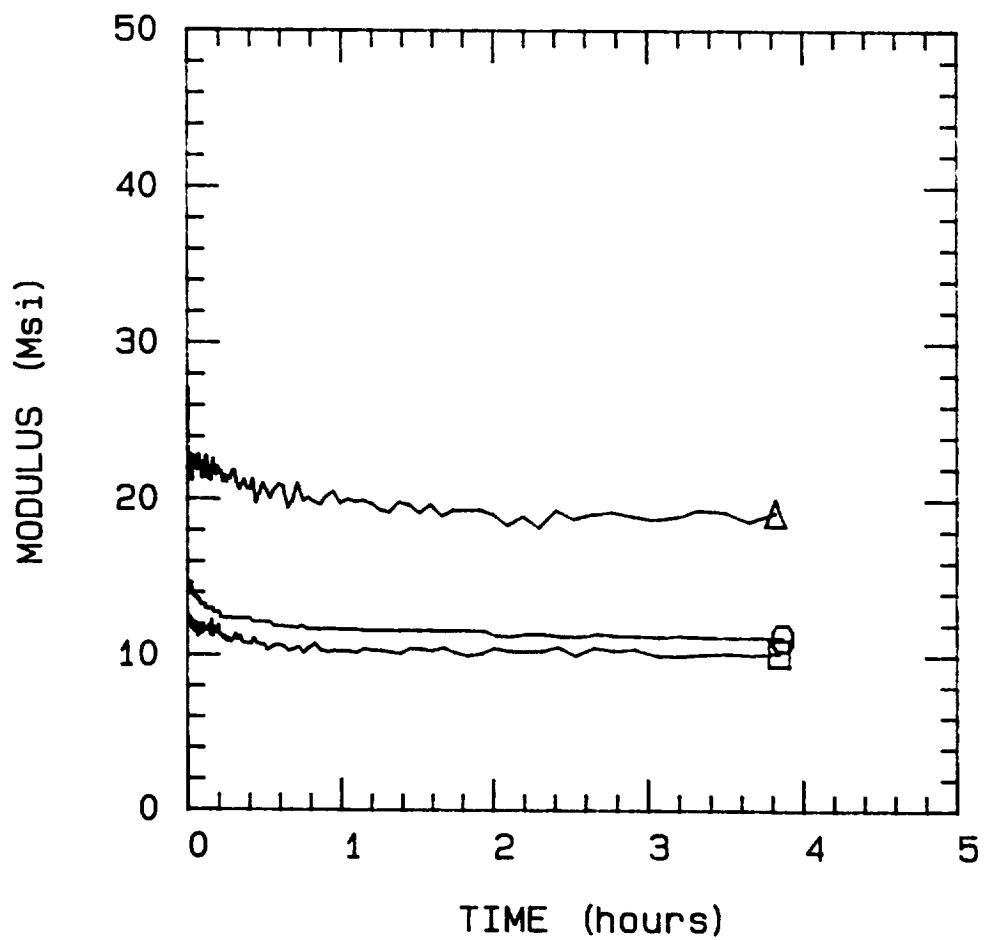
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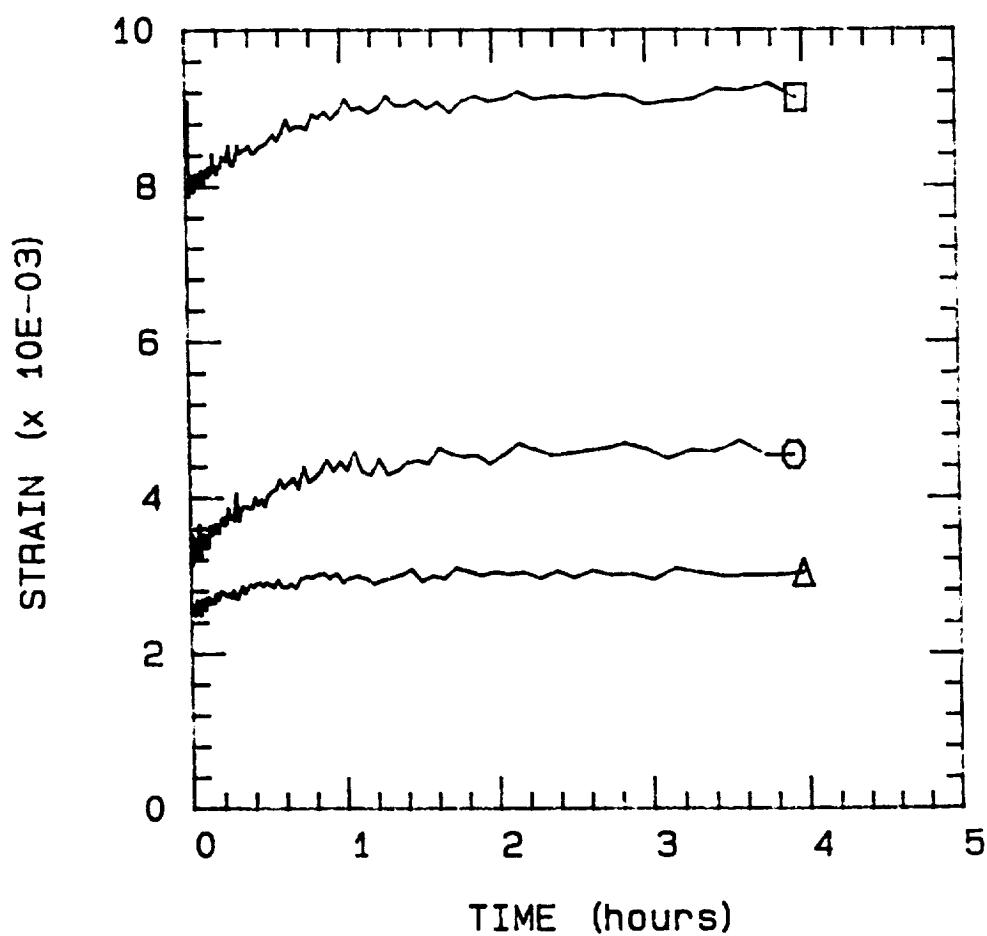
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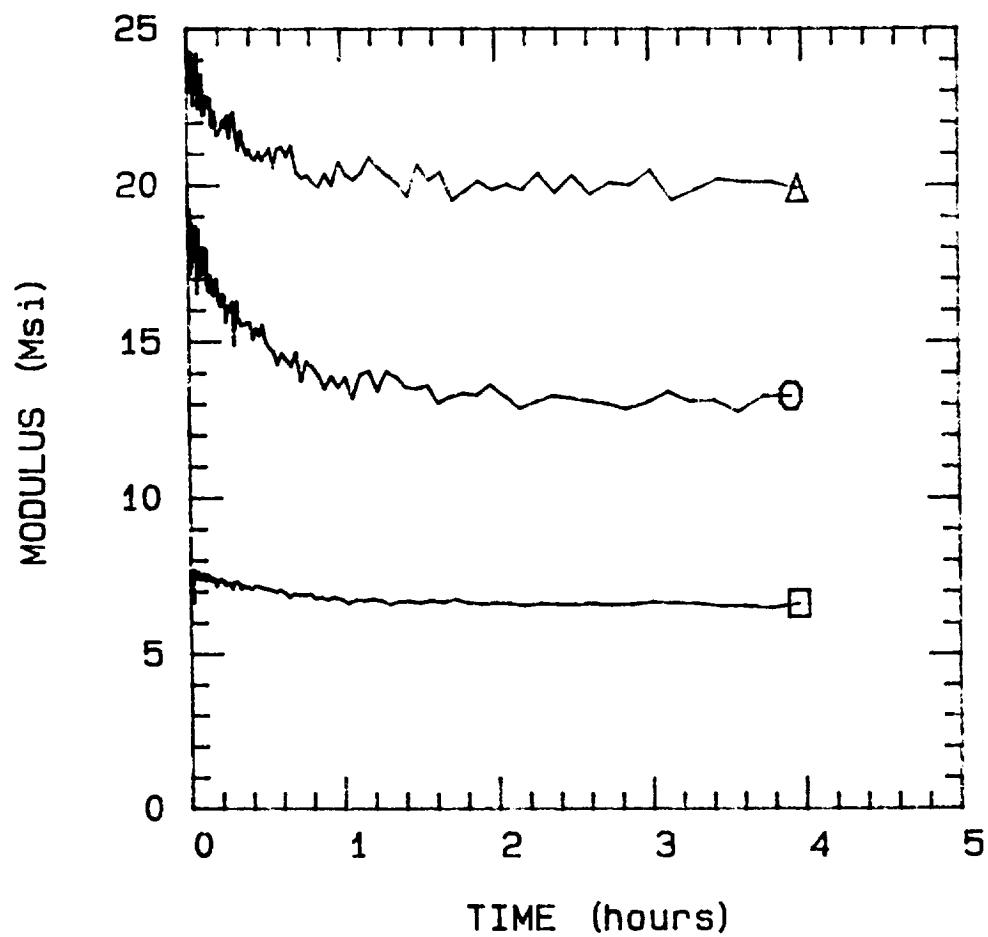
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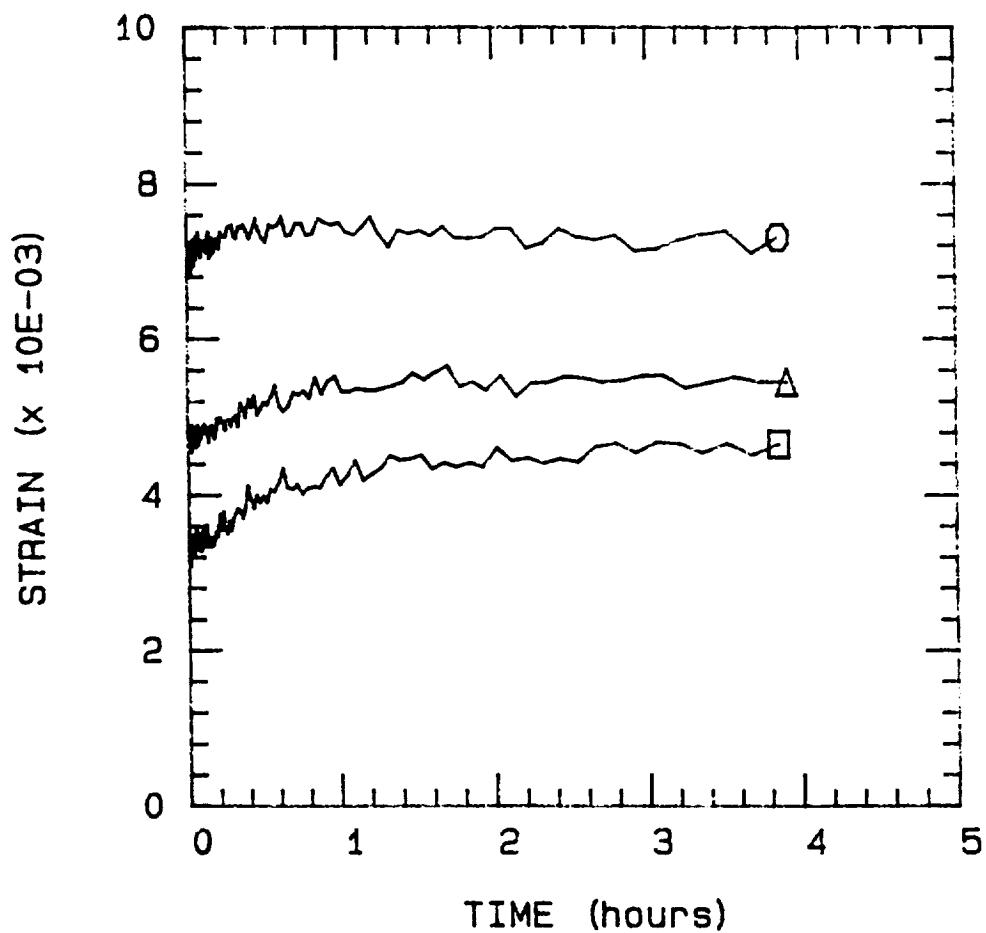
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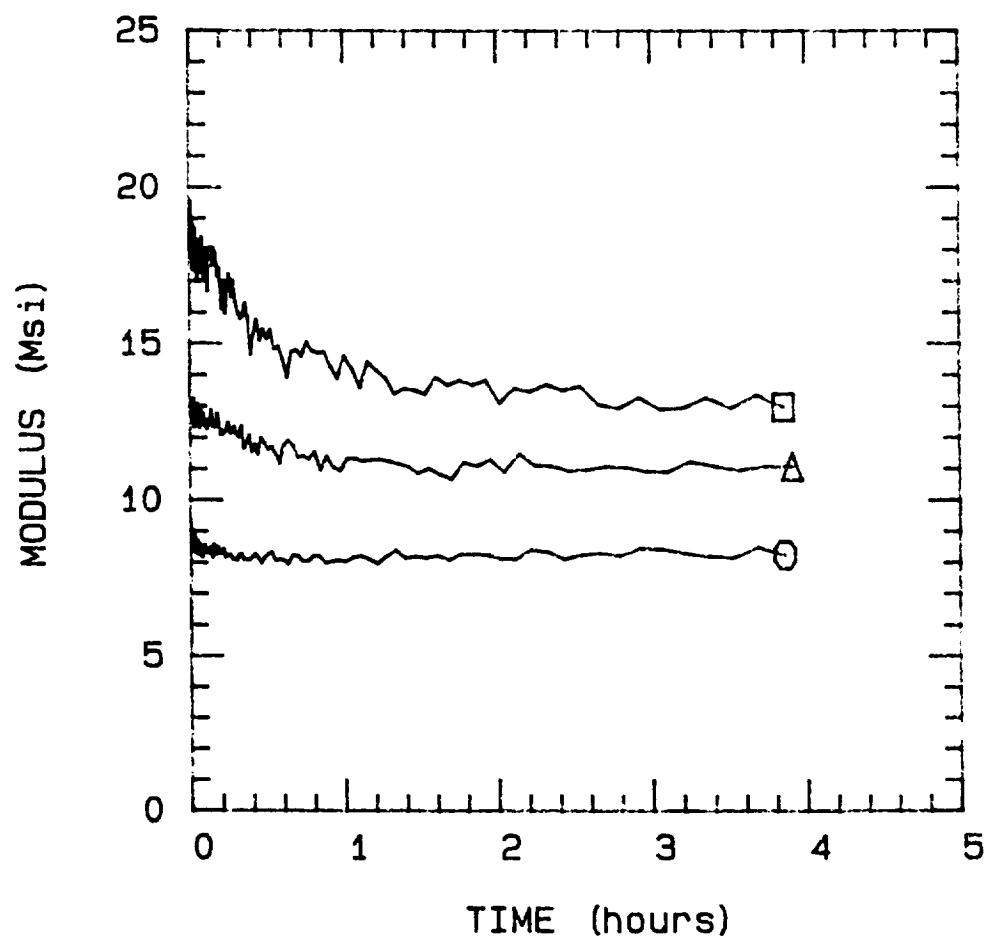
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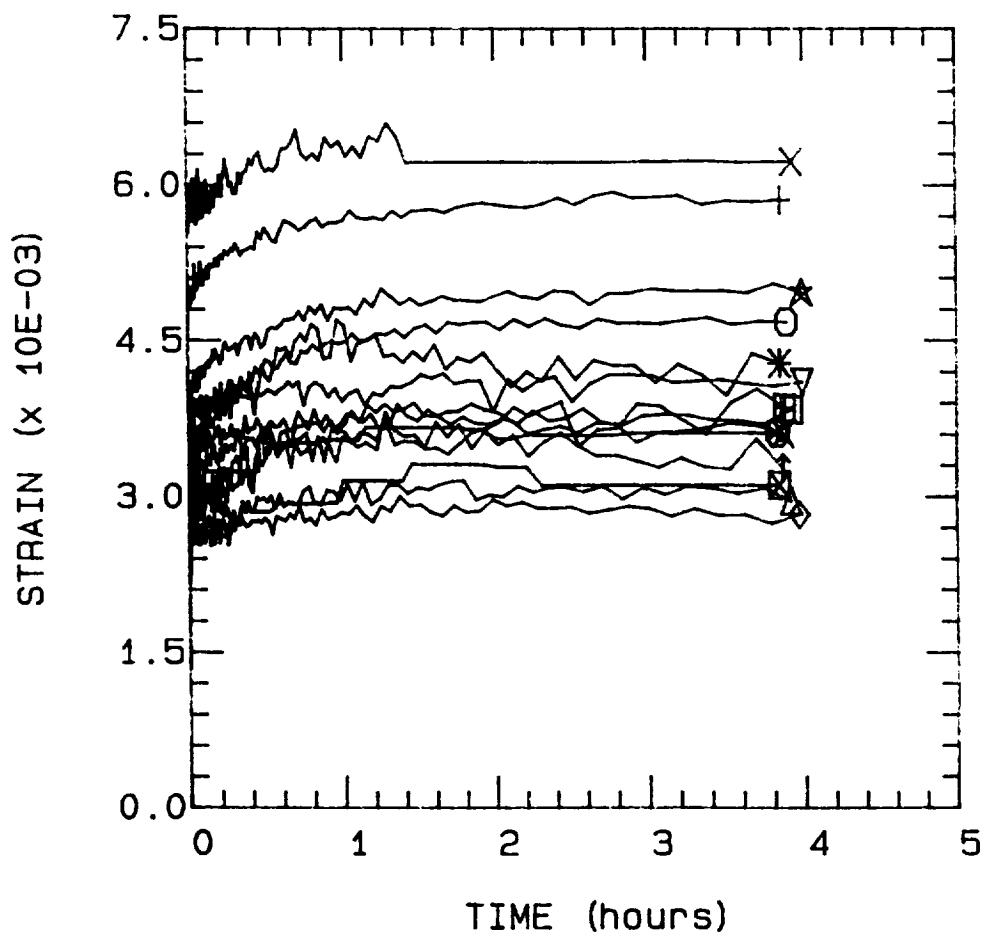
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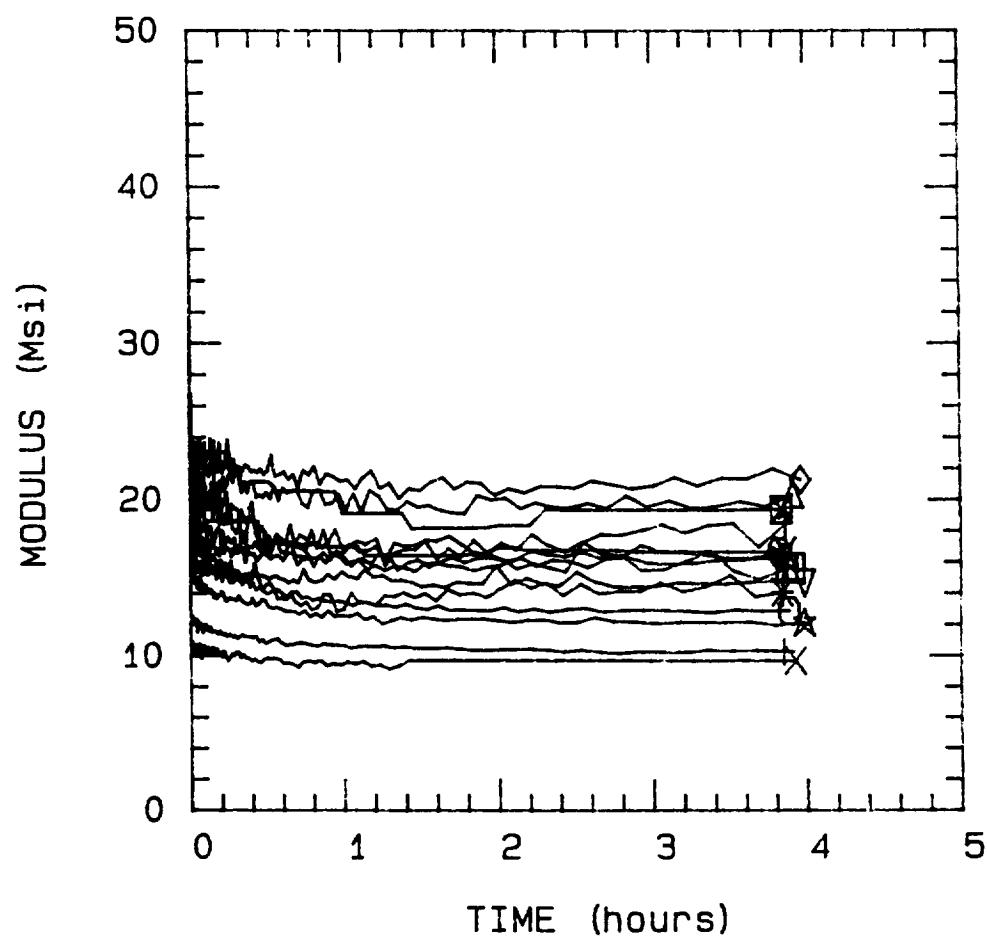
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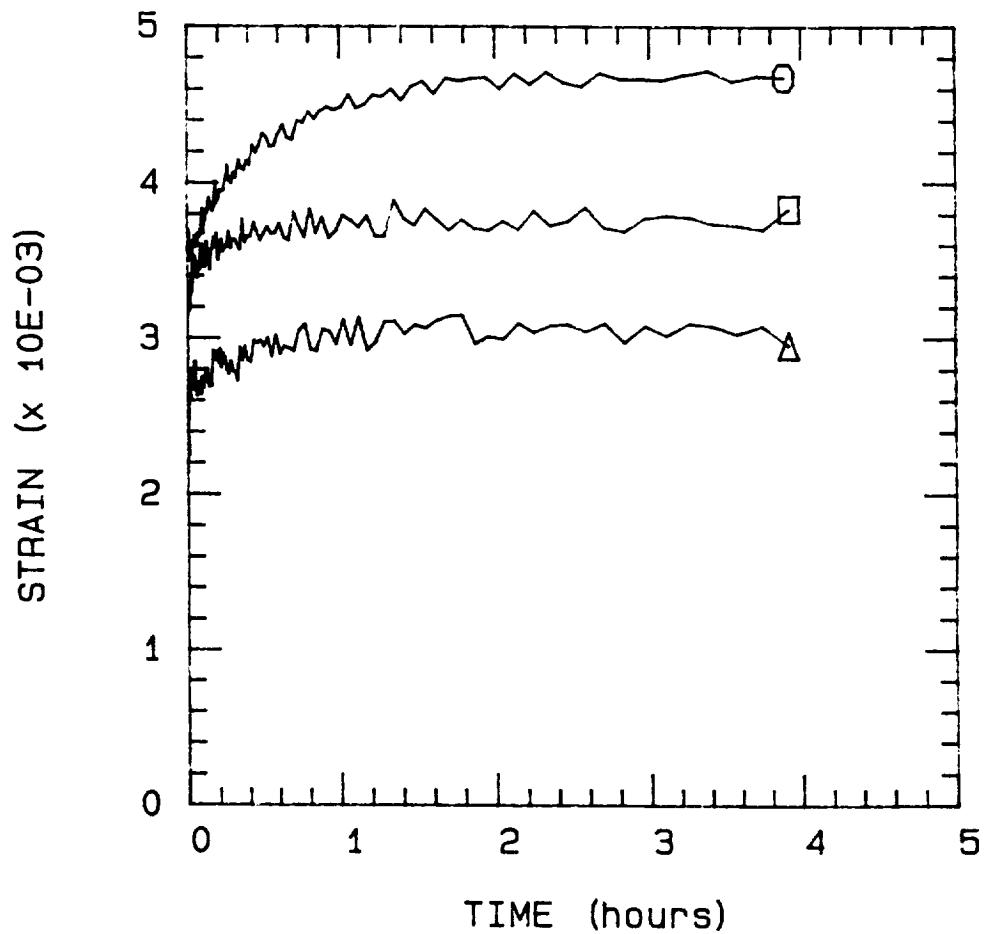
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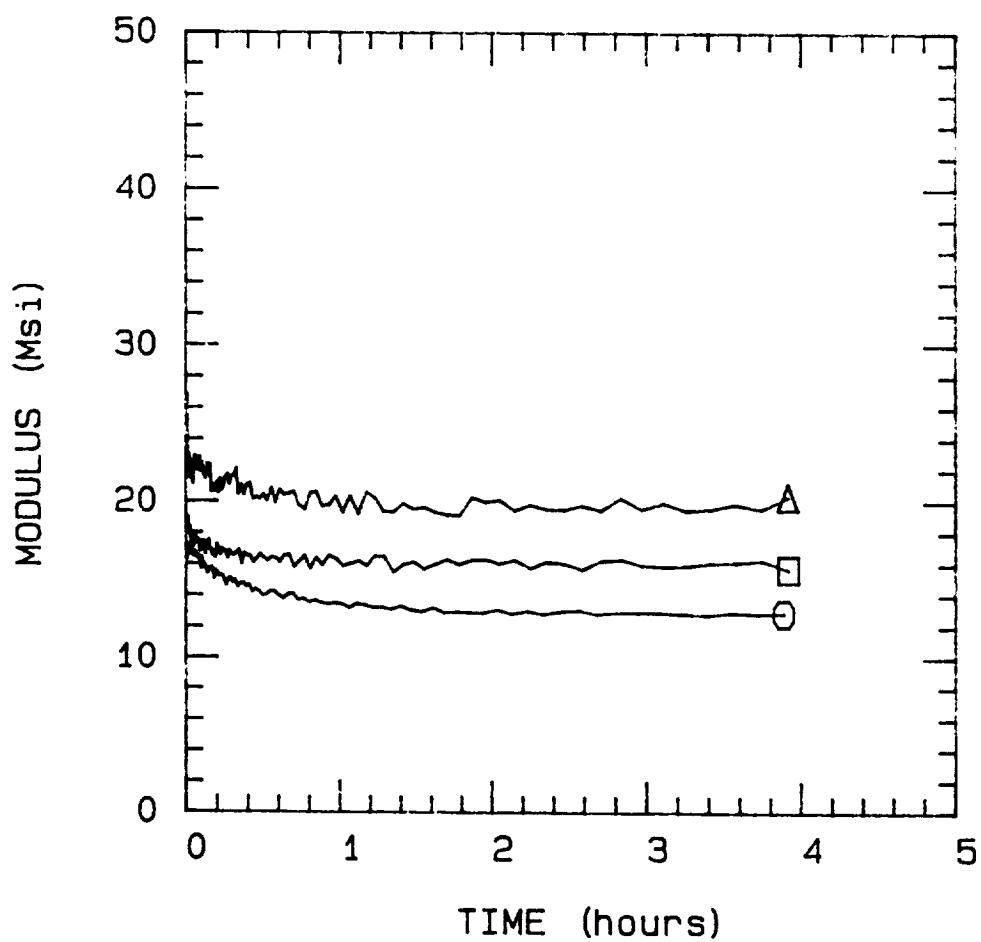
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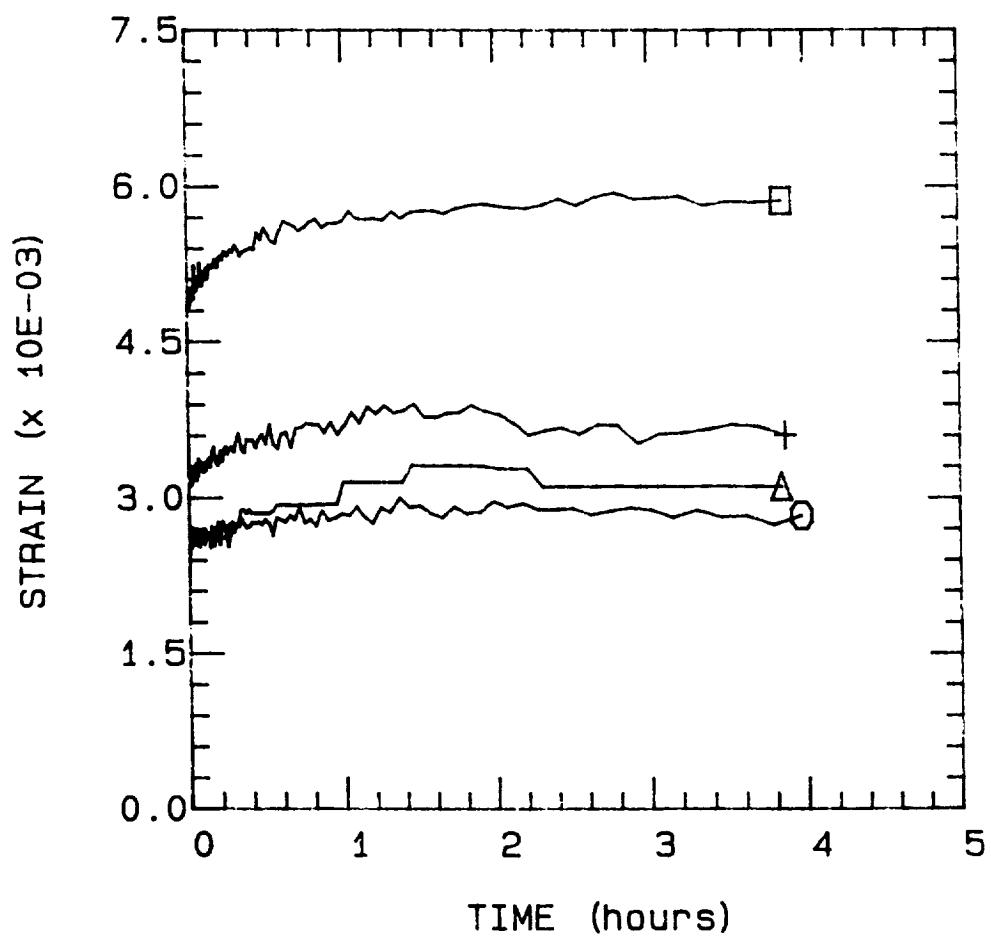
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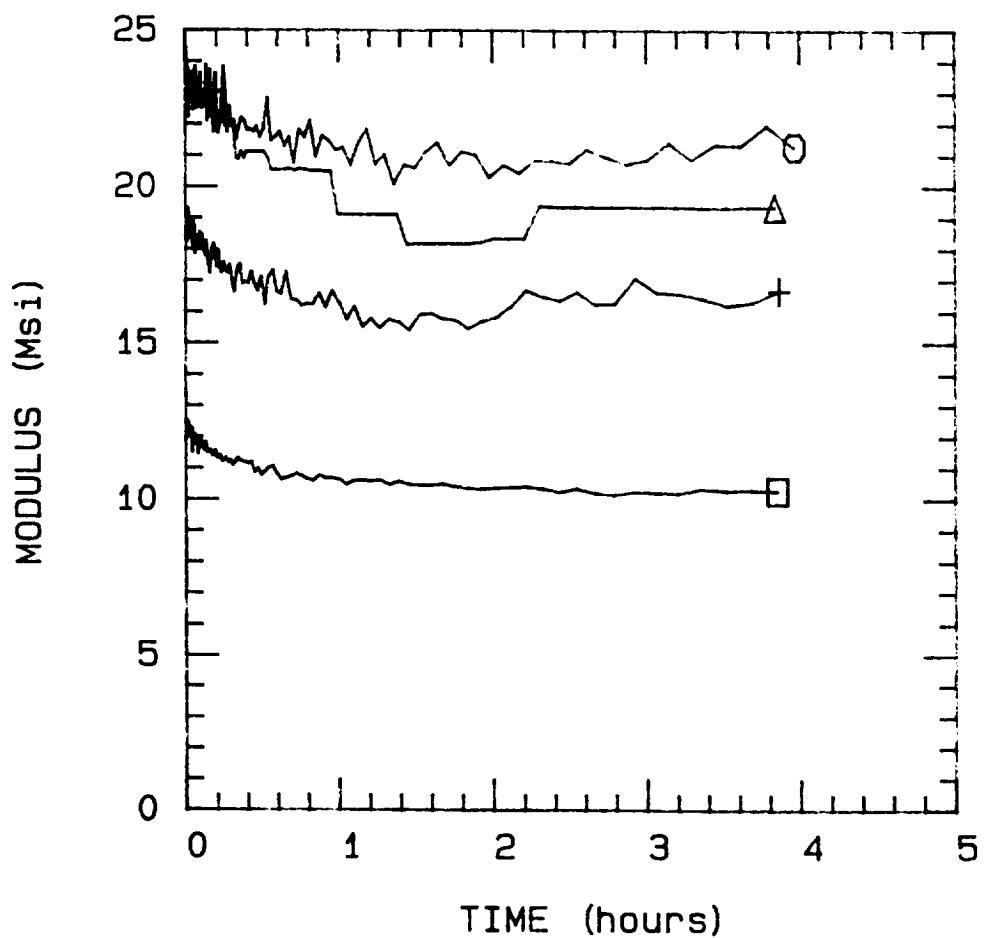
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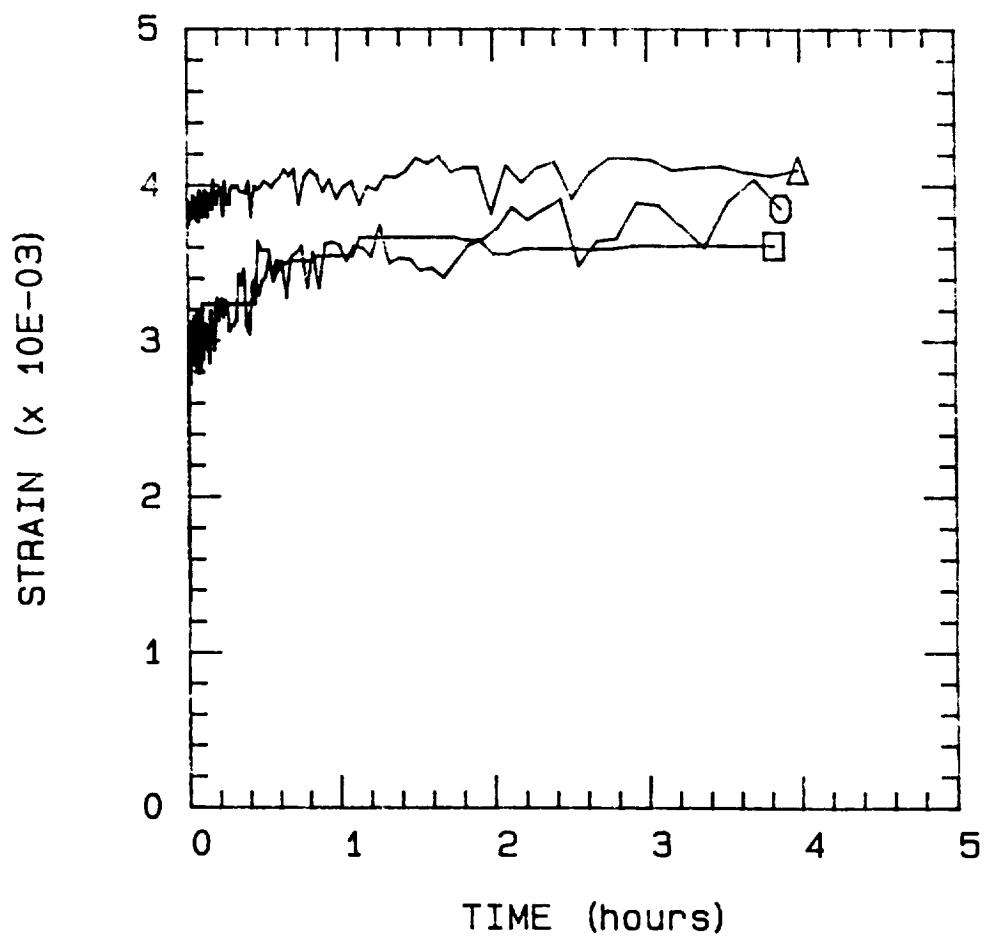
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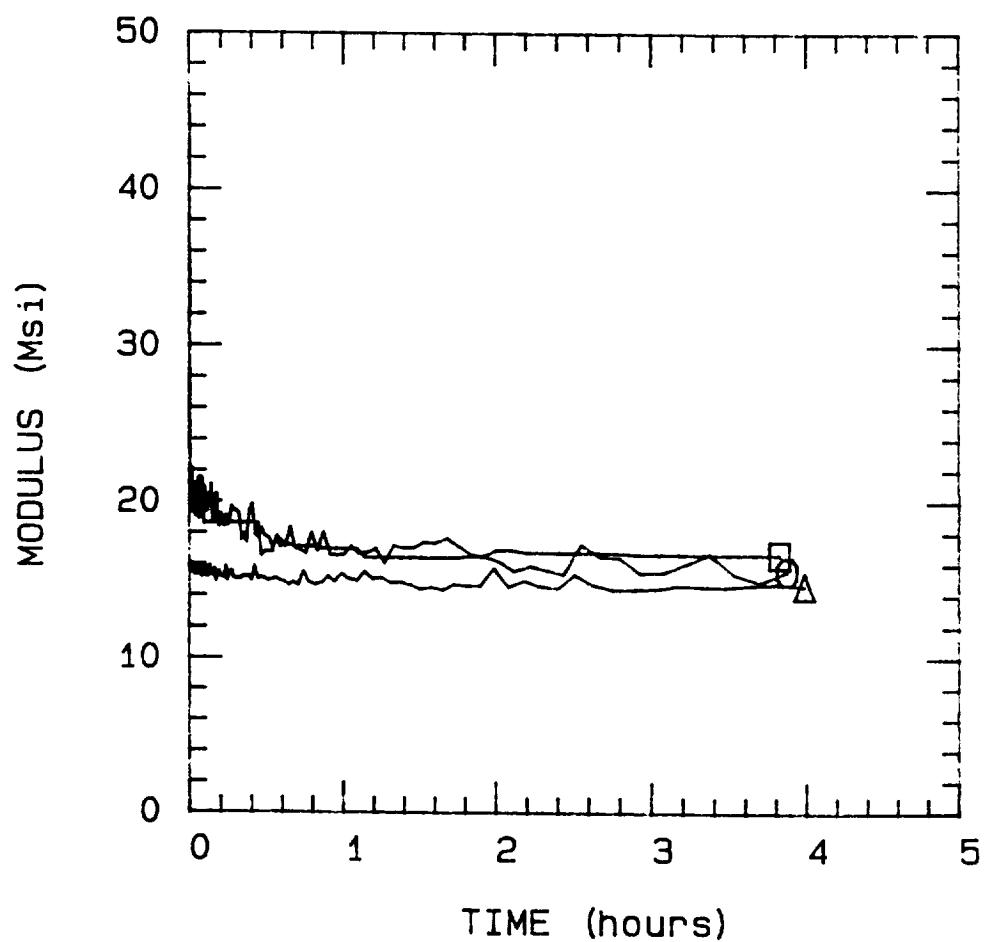
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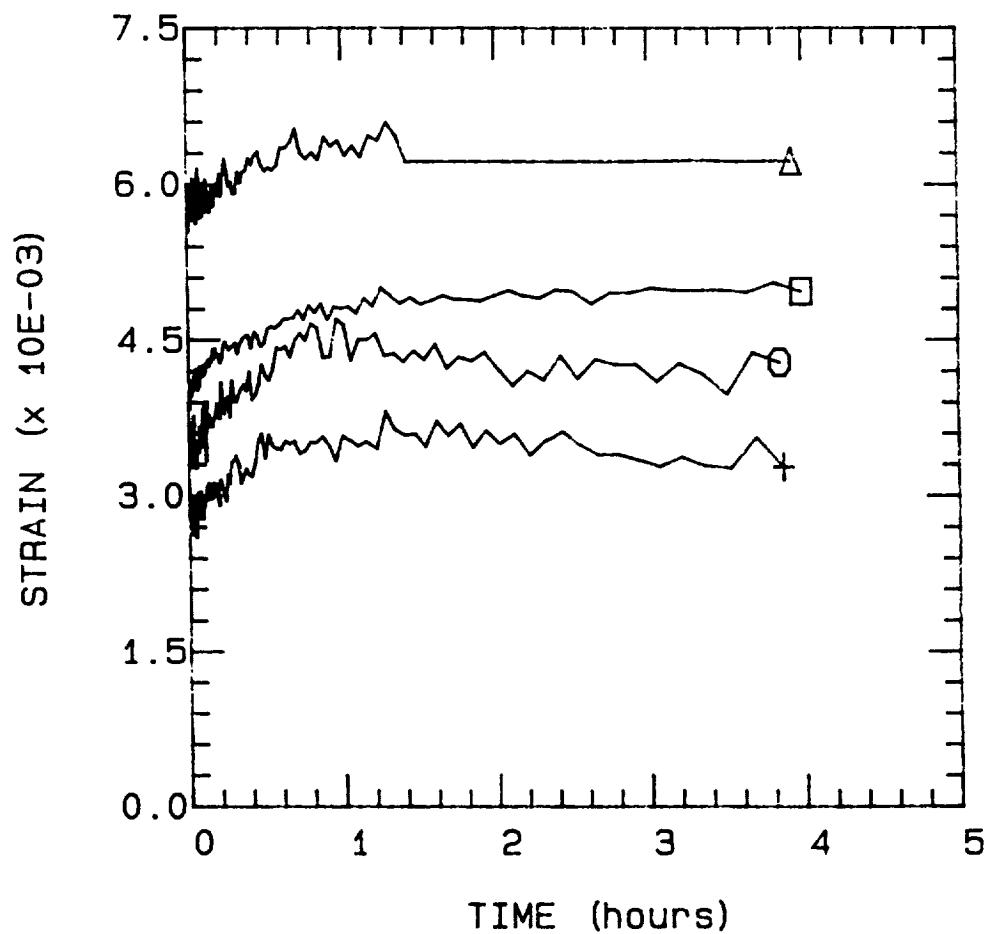
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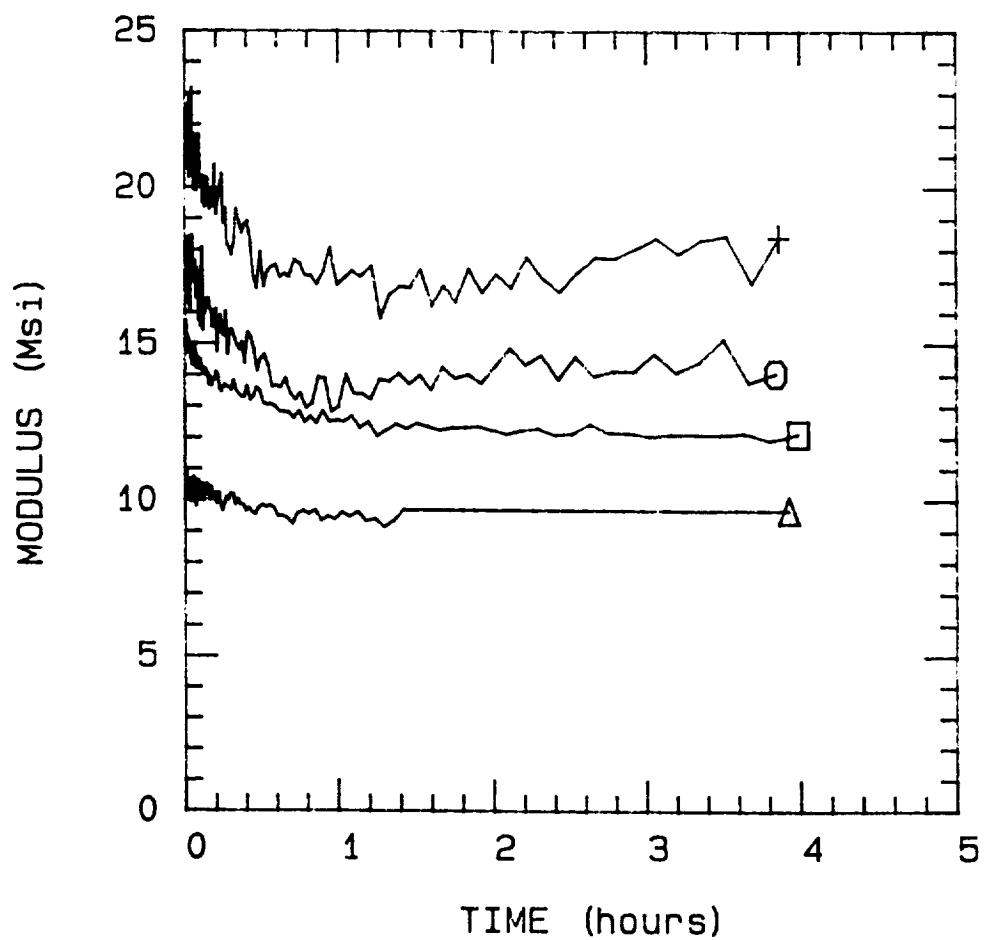
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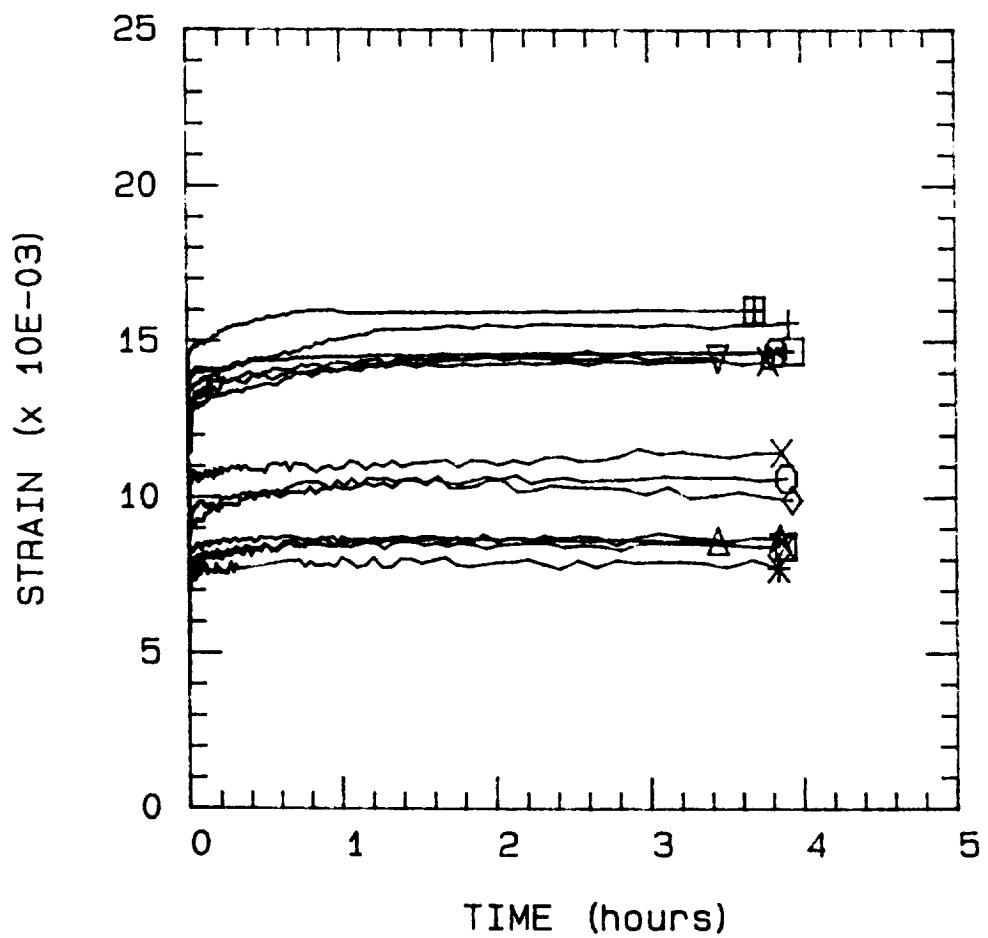
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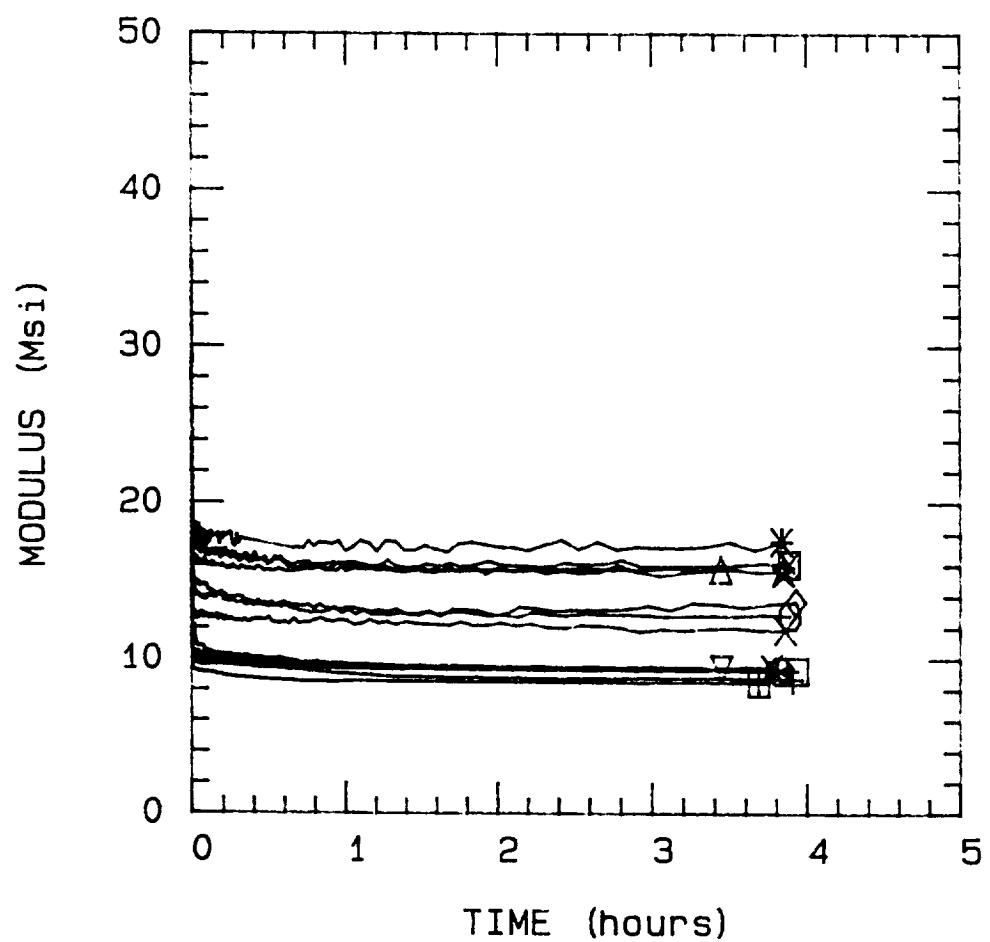
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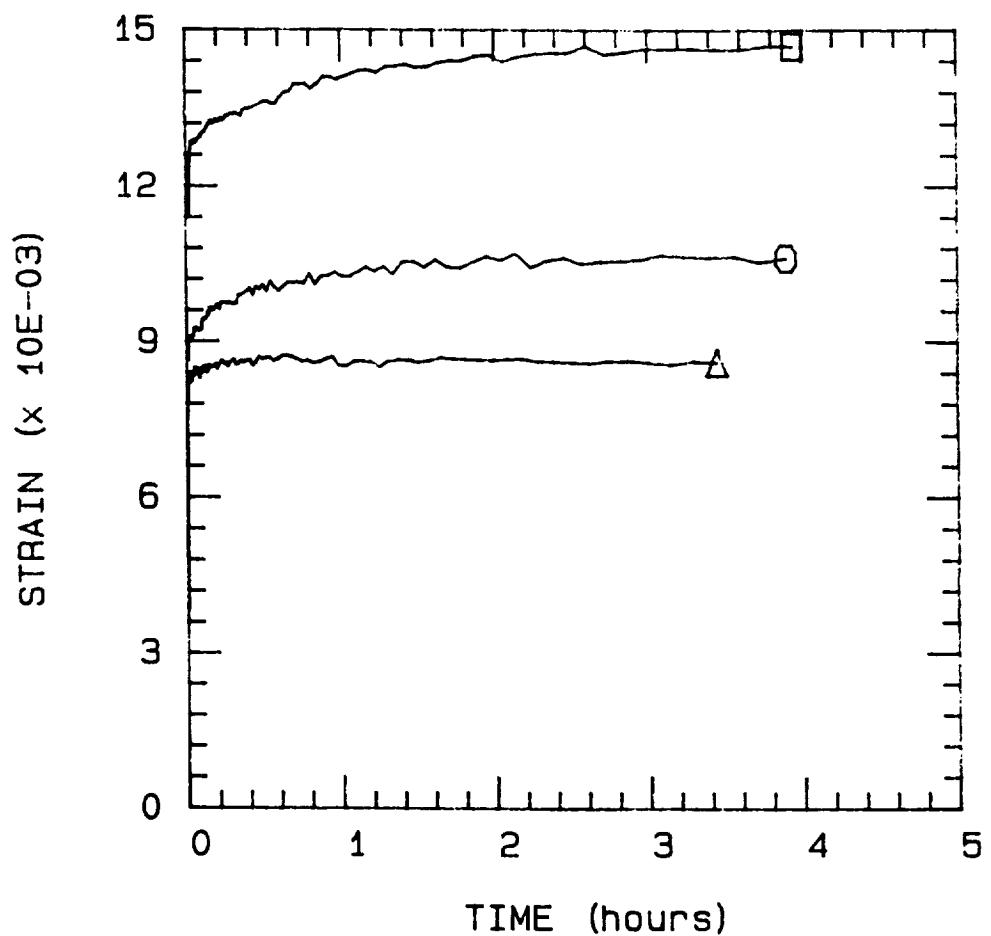
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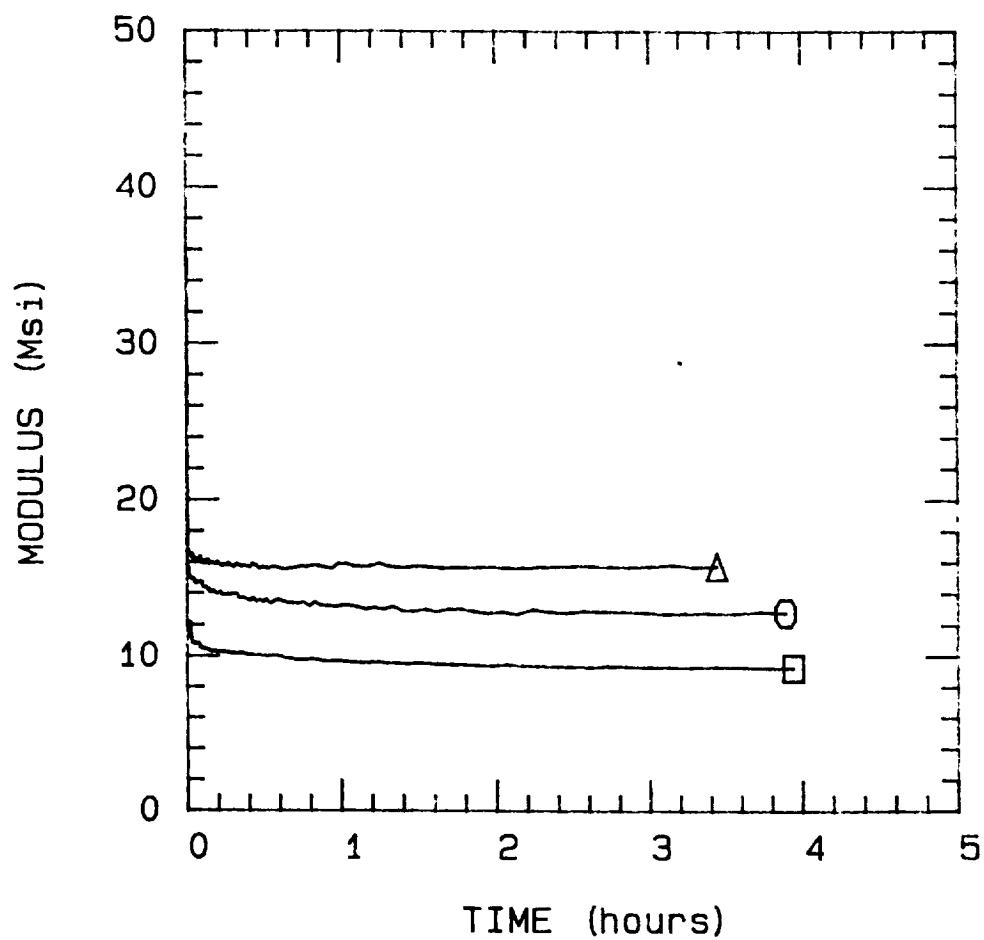
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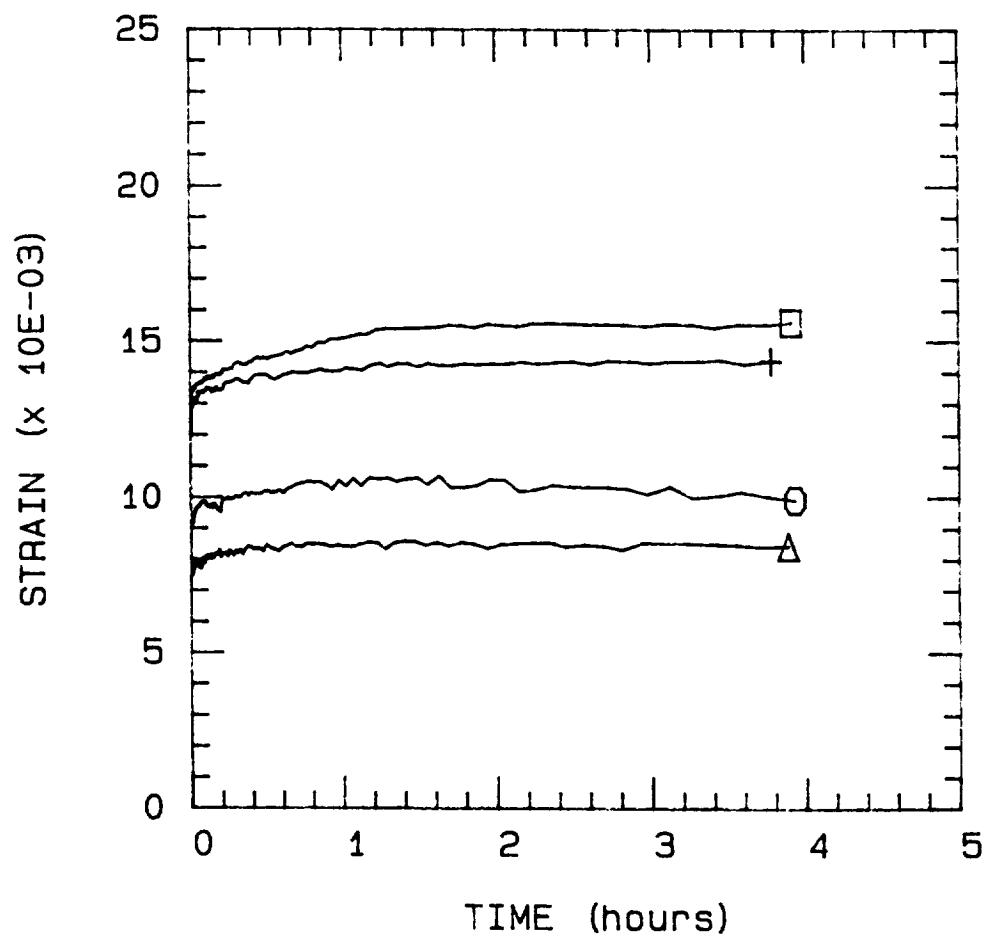
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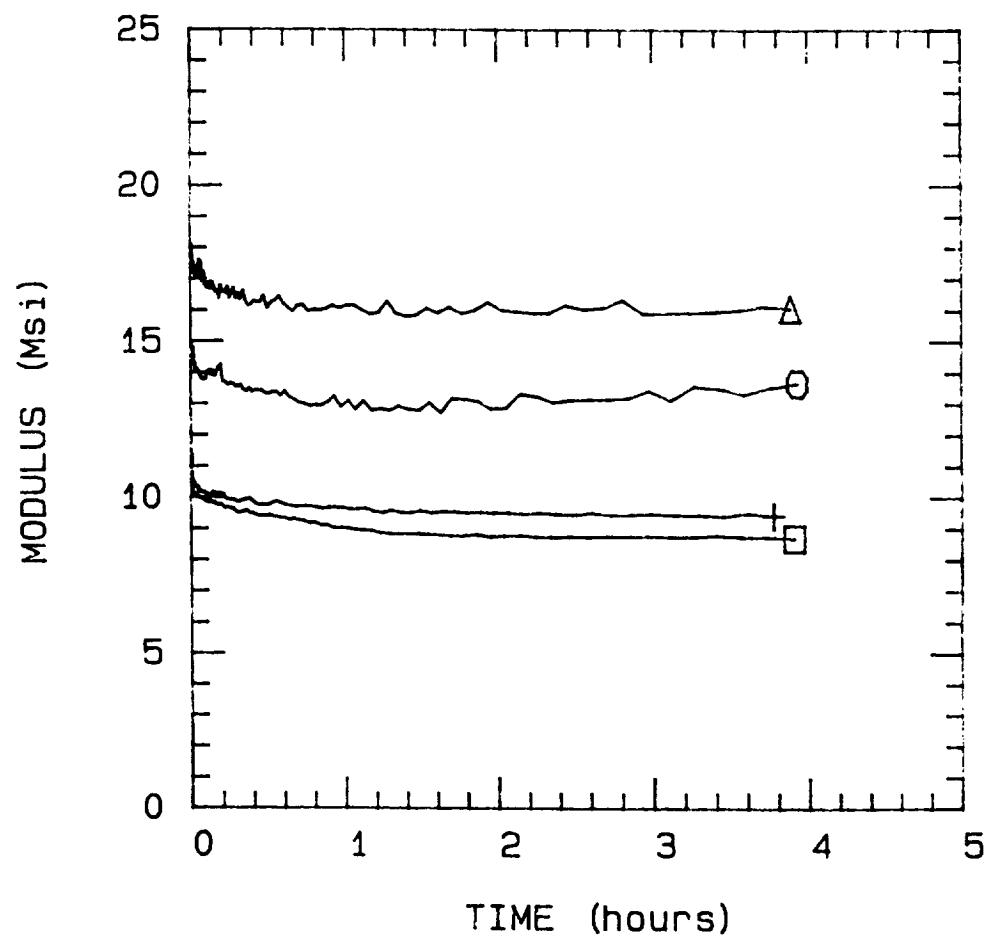
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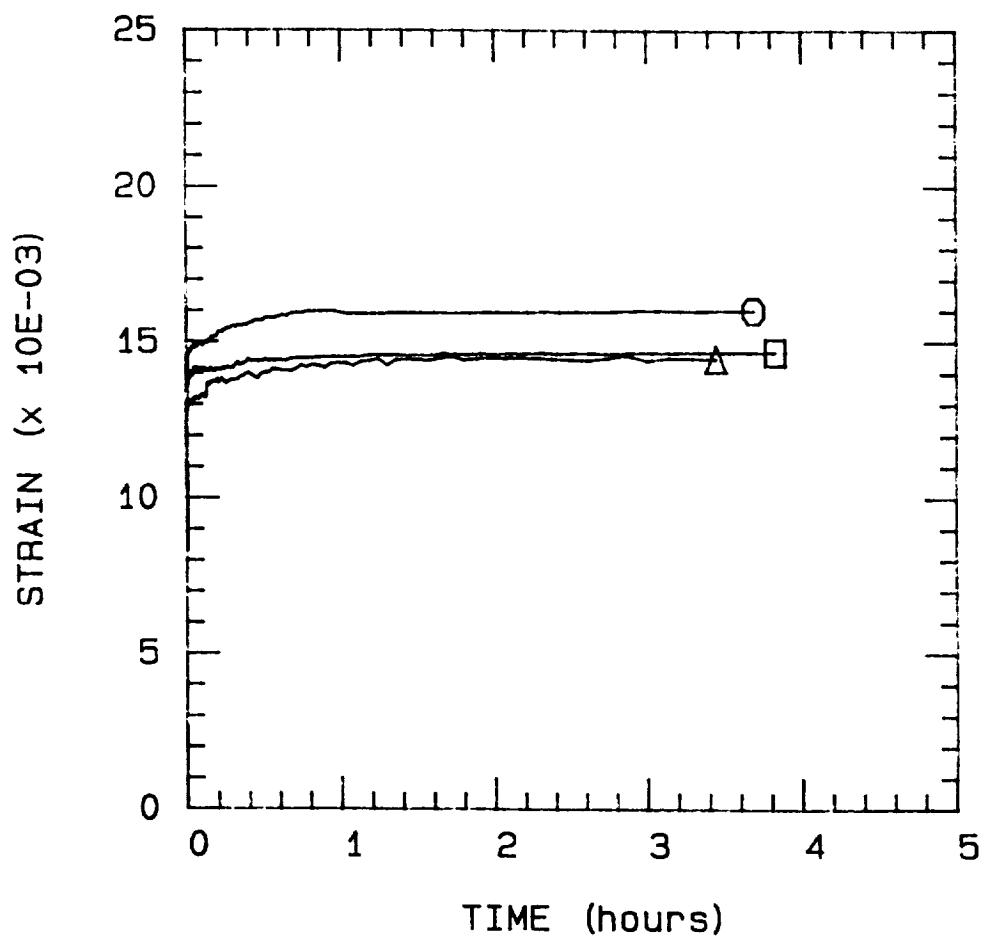
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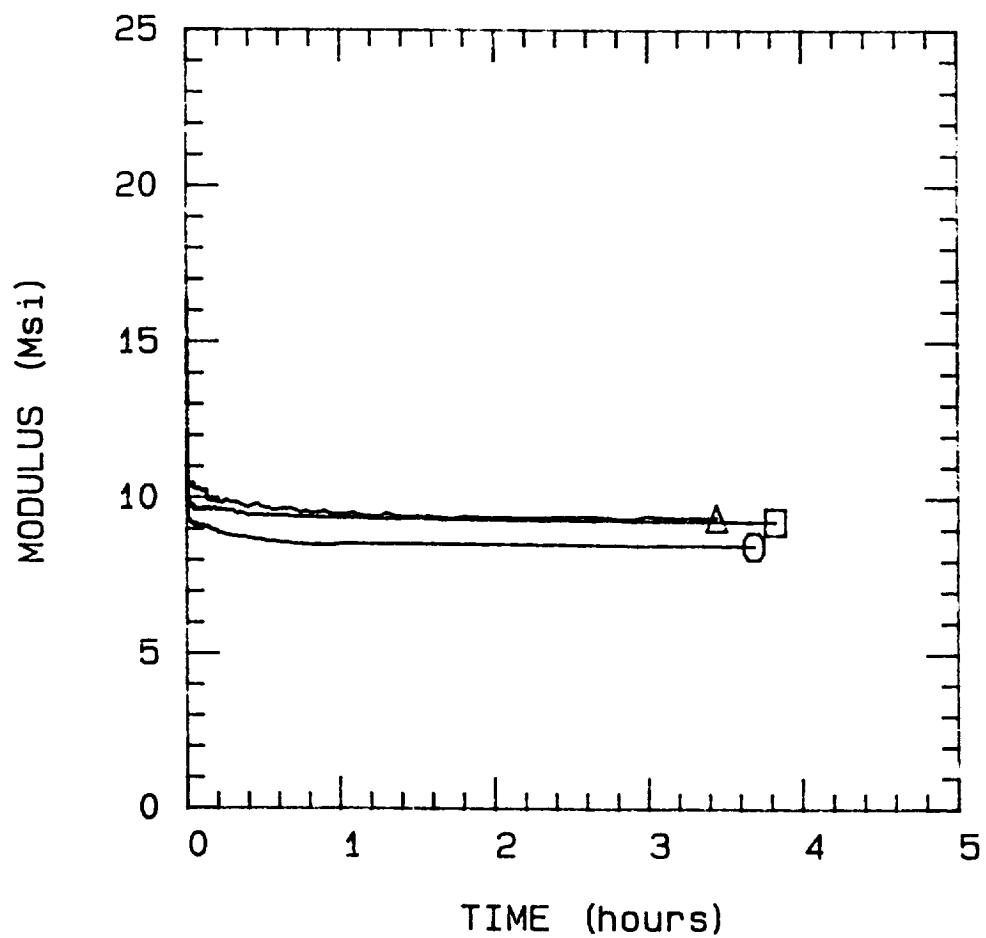
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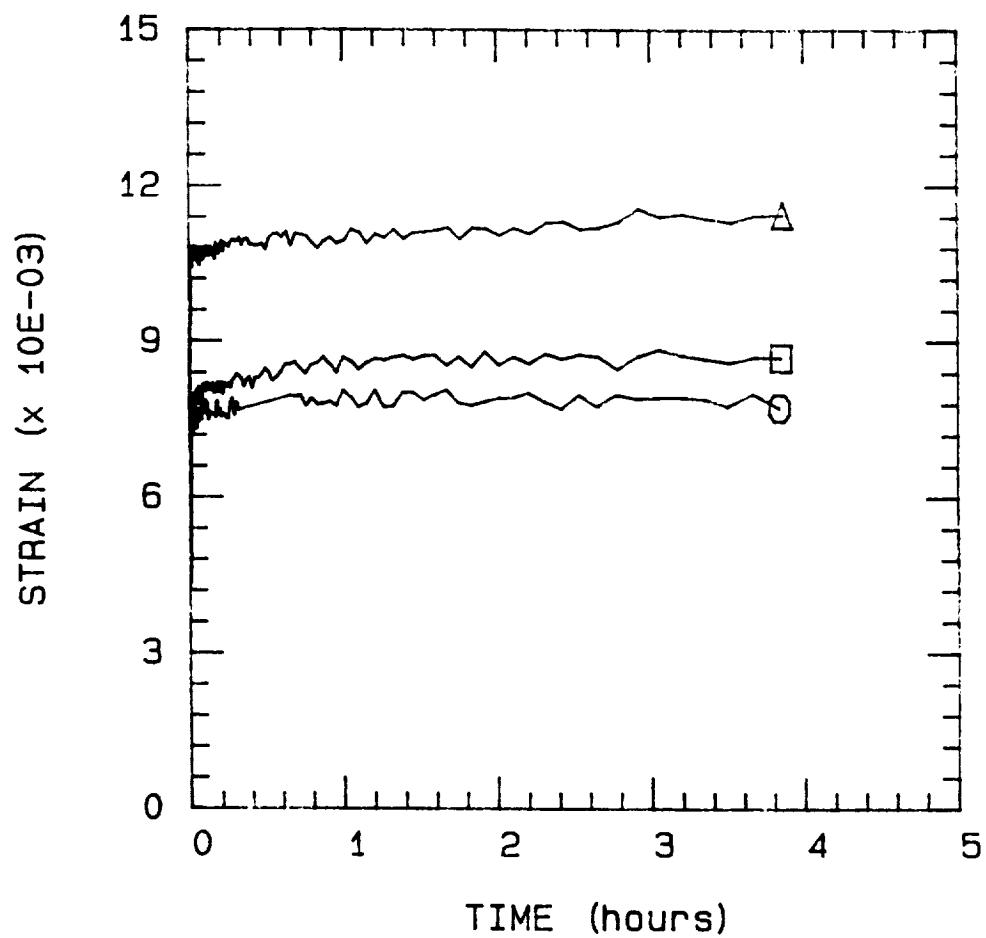
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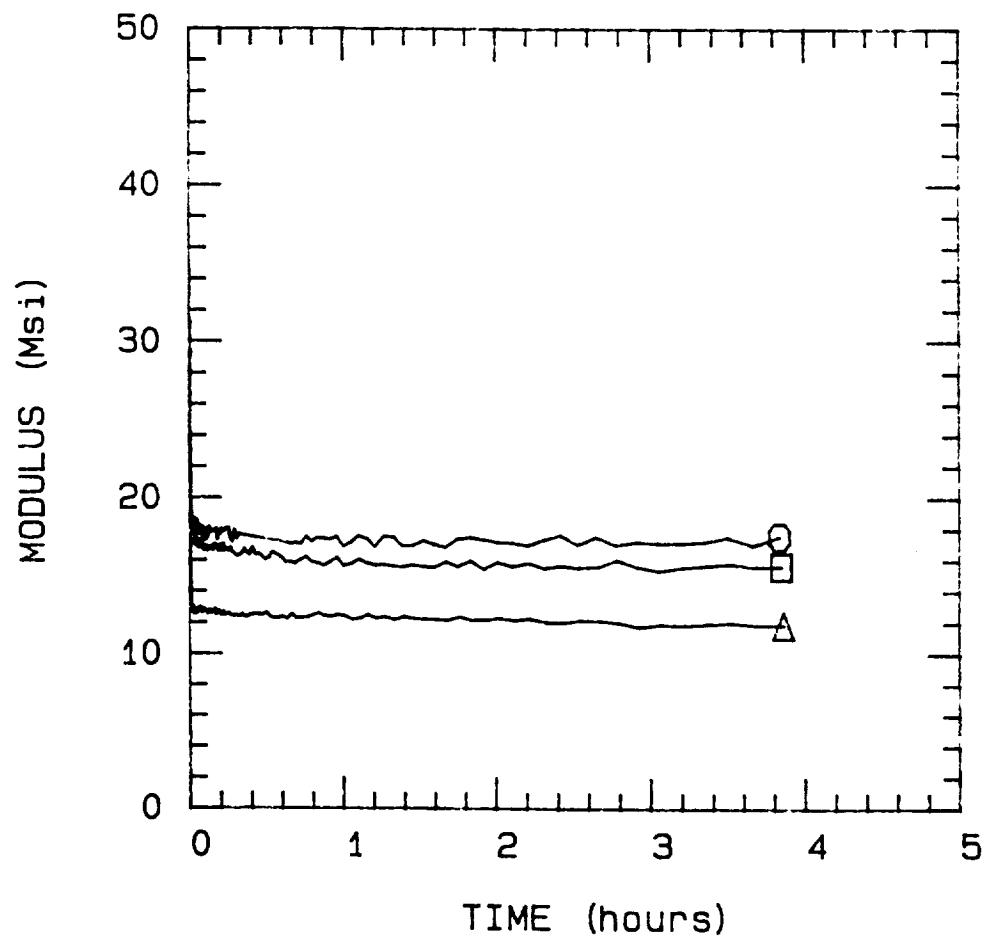
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| 16. Abstract <p>Six types of uncoated ceramic fibers, viz., J. P. Stevens Co. Astroquartz 9288 glass, Nippon Carbon, Ltd. (Dow Chemical) Nicalon NLM-102 silicon carbide, and 3M Company Nextel 312, Nextel 380, Nextel 440 and Nextel 480 alumina/silica/boria, were static tensile and tensile creep tested at various elevated temperatures. Boron nitride coated Nicalon NLM-102 and Nextel 312, 440 and 480 fibers were also tested.</p> <p>Room temperature static tensile tests were initially performed on all fibers, at gage lengths of 1", 2", and 4", to determine the magnitude of end effects from the gripping system used. Tests at one elevated temperature, at gage lengths of 8" and 10", were also conducted, to determine end effects at elevated temperatures.</p> <p>Fiber cross-sectional shapes and areas were determined using scanning electron microscopy.</p> <p>Creep testing was typically performed for four hours, in an air atmosphere.</p> | | | |
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